Distribution. The member occurs along the length of Neill Klinter, at Harris Fjeld and as far north as Dusén Bjerg, where it wedges out.

Geological age. Body fossils are generally rare and none are age diagnostic. Palynomorphs suggest a Late Pliensbachian age (Koppelhus & Dam, in press).

Ostreaelv Formation

new formation

History. This formation corresponds to the Ostreaelv Member of Surlyk *et al* (1973).

Name. The formation is named after the river Ostreaelv, in the south-eastern part of Jameson Land, where the uppermost part of the formation is well-exposed (Fig. 1; Surlyk *et al.*, 1973).

Type locality and reference localities. The upper part of the formation is well-exposed at Ostreaelv (Surlyk *et al*, 1973). This is designated the type section. Well-exposed reference sections occur along Neill Klinter at Albuen, at Harris Fjeld and Nathorst Fjeld and at Lepidopteriselv and Horsedal (Fig. 1).

Thickness. The formation is less than 90 m at the type locality, 125 m at Albuen, 122 m at Harris Fjeld, more than 112 m at Nathorst Fjeld, 157 m at Liaselv and more than 155 m at Horsedal.

Lithology. The Ostreaelv Formation has a very variable lithological composition. One of the most distinctive characteristics of the formation is the appearance of body fossils that are very rare in the underlying Gule Horn Formation. At the type section, along Neill Klinter, and at Nathorst Fjeld the formation is dominated by fine to very coarse-grained sandstones. Many sandstones are cross-bedded and rhythmical clay drapes are common on the foresets. Concretionary cement has hardened some beds. At Lepidopteriselv the formation consists of medium to very coarse-grained, concretionary, cross-bedded sandstones, occasionally with logs, interbedded by bioturbated sandy mudstones. From Lepidopteriselv westwards towards Liaselv and southwards the cross-bedded sandstones pass laterally into medium-grained bioturbated sandstones. At Horsedal the formation is initiated with a unit of thin coarsening-upward successions composed of sand-streaked mudstones grading upward into fine to medium-grained sandstones. Coal seams and rootlet beds commonly occur on top of the coarsening-upward successions. This unit is overlain by a unit composed of cross-bedded, cross-laminated, parallel-laminated and hummocky cross-stratified fine to medium-grained sandstones alternating with bioturbated sandstones. At this locality thin conglomerates, composed of discoidal quartzite pebbles, occur at several levels.

Fossils. Body fossils occur at several horizons, most commonly in those hardened by concretionary cement. Rosenkrantz (1934) identified a diverse, dominantly European fauna of 69 species, dominated by bivalves and including brachiopods, crinoids and cephalopods. Fish scale and rootlet horizons have also been found in the Horsedal Member. Trace fossils are common and include *Arenicolites* isp., *Cochlichnus anguineus, Cruziana* isp., *Curvolithos multiplex, Diplocraterion habichi, Diplocraterion paralellum, Gyrochorte comosa, Gyrophyllites kwassicensis, Helminthopsis magna, Lockeia amygdaloides, Nereites* isp., *Ophiomorpha nodosa, Palaeophycus* isp., *Parahaentzschelinia surlyki, Phoebichnus trochoides, Phycodes bromleyi, Planolites beverleyensis, Scolicia* isp., *Taenidium serpentinum, Teichichnus* isp., *Thalassinoides* isp., *Rhizocorallium irregulare,* and *Rhizocorallium* isp.

Boundaries. Along Neill Klinter the lower boundary is sharp and placed between the alternating sandstones and mudstones of the Albuen Member and the overlying cross-bedded sandstones of the Astartekløft Member. In the northern and central parts of the basin the lower boundary is placed where cross-laminated and cross-bedded sandstones of the Elis Bjerg Member give way to wave ripple cross-laminated, parallel laminated and hummocky cross-stratified sandstones arranged in small coarsening-upward successions of the Horsedal Member.

Throughout the exposed part of the basin the upper boundary of the formation, between the sandstones of the Trefjord Bjerg Member and the dark mudstones of the Sortehat Formation, is flat, very sharp and in places pebble strewn.

Distribution. Same as for the group.

Geological age. Palynomorphs, belemnites and ammonites suggest a latest Pliensbachian – earliest Aalenian age of the formation (Doyle, 1991; J. H. Callomon, personal communication, 1993; Koppelhus & Dam, in press).

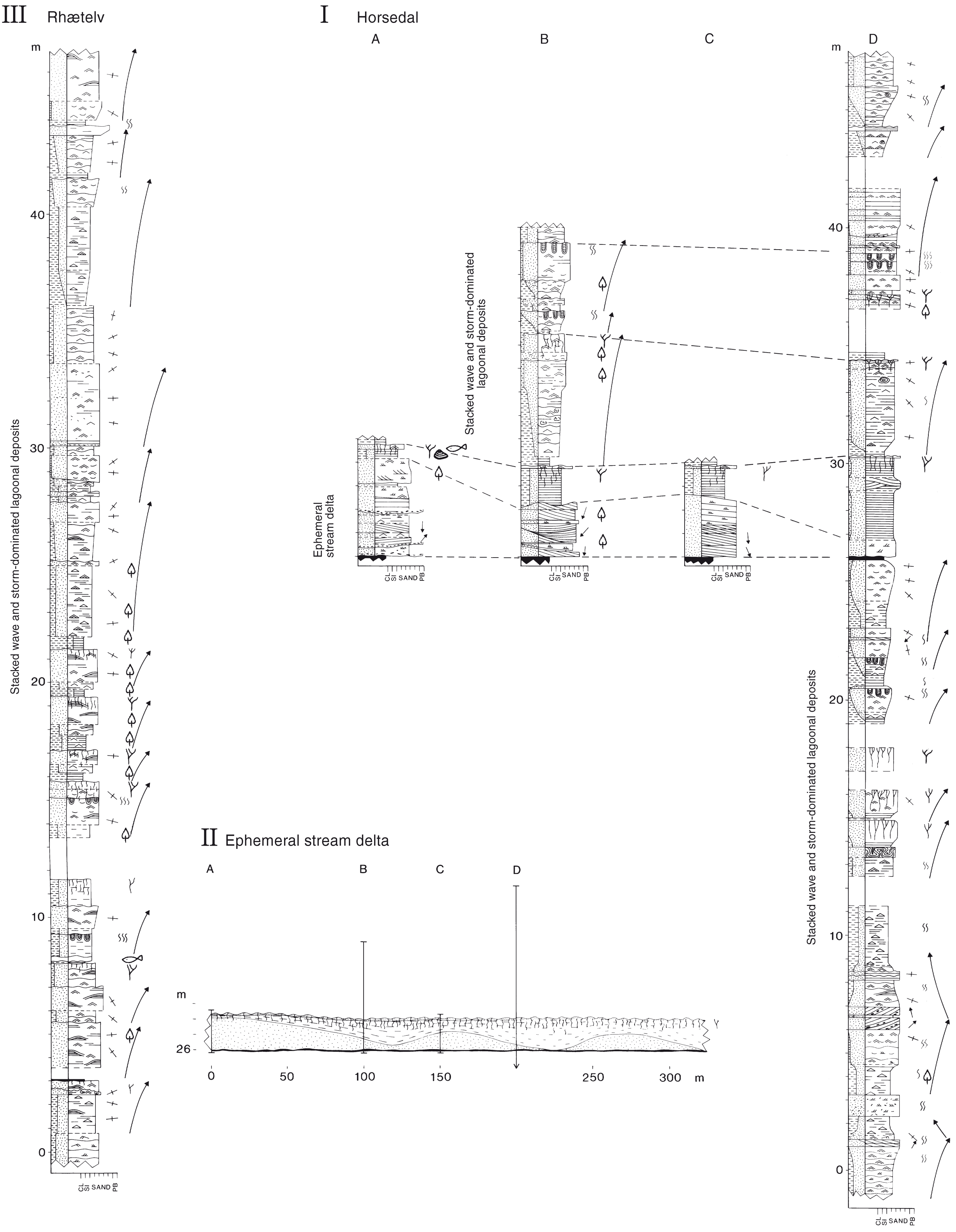


Fig. 24. Sedimentological logs through stacked wave and storm-dominated coarsening-upward lagoonal (Facies association k) and ephemeral stream delta (Facies association l) deposits of the Horsedal Member. I = section measured in Horsedal; II = lateral profile showing the morphology of the ephemeral stream delta deposits in Horsedal. Vertical lines show location of vertical profiles from I; III = section measured in Rhætelv, *c.* 25 km south of Horsedal. See Fig. 1 for locations and Plate 1 for legend.

Fig. 25. Stacked, coarsening-upward sheet sandstones formed by repeated progradation of the shoreface into a wave and storm-dominated lagoon (Facies association k). Horsedal Member, Horsedal. See Fig. 1 for location. Encircled person for scale.

Subdivisions. The formation is subdivided into seven members. They are the Horsedal, Astartekløft, Lepidopteriselv, Harris Fjeld, Nathorst Fjeld, Skævdal and Trefjord Bjerg Members (Fig. 3).

Horsedal Member

new member

History. The sediments of this member have not previously been recognised as a stratigraphic unit. It has not been possible to decide whether the sediments were included in the Ostreaelv or Gule Horn Members (*sensu* Surlyk *et al.*, 1973) in previous studies.

Name. The member is named after the valley Horsedal north of Ørsted Dal, in Scoresby Land (Fig. 1).

Type and reference localities. Two nearly complete sections occur in Horsedal and at Rhætelv; the former is chosen as type section and the latter as reference section (Figs 1, 24).

Thickness. The member is 58 m thick at the type locality and 50–55 m at Rhætelv and Liaselv.

Lithology. The member is dominated by thin coarsening-upward successions, 1–6 m thick, composed of sand-streaked mudstones grading upward into fine to medium-grained sandstones. Coal seams and rootlet beds commonly occur on top of the coarsening-upward units. Parting planes often show wave ripples.

Facies associations and depositional environments. Two facies associations are recognised in the Horsedal Member (k and l).

k. Wave and storm-dominated lagoonal association. This association is characteristic of the member and consists of small coarsening-upward units, 1–6 m thick (Figs 24, 25). The lower part of the units consists of streaked mudstones. The streaks are composed of fine-grained silty sandstones showing incipient wave ripple lamination (cf. Facies M_1 of De Raaf *et al.*, 1977). The lower streaked mudstones grade upward into wavy and flaser-bedded heterolithic deposits and fine to medium-grained sandstones. The wavy and flaser-bedded deposits show a large variety of structures typical of wave action (cf. Facies M_2 and S_1 of De Raaf *et al.*, 1977). A maximum depositional water depth for these sediments of approximately 10 m is estimated on the basis of wave ripple features following the method of Diem (1985). The fine to medium-grained sandstones are low-angle cross-bedded, parallel laminated or massive. Beds of single and amalgamated hummocky and swaley cross-stratified, fine-grained sandstones occur within the coarsening-upward successions. Root-like structures occasionally occur in distinct wave-worked beds on top of the coarsening-upward units. They are vertical, sand-filled and have a thin coaly lining. They commonly show upward dichotomous branching, and thin bituminous coal seams may overlie the beds.

The *Diplocraterion parallelum* ichnocoenosis characteristic of this association is generally monospecific, including only *Diplocraterion parallelum*, but *Arenicolites* isp., *Cochlichnus anguineus, Helminthopsis magna, Lockeia amygdaloides* and *Planolites beverleyensis* may occur (Dam, 1990b). *D. parallelum* is restricted to certain levels, which are strongly bioturbated (up to 100%), and can be followed for several hundreds of metres.

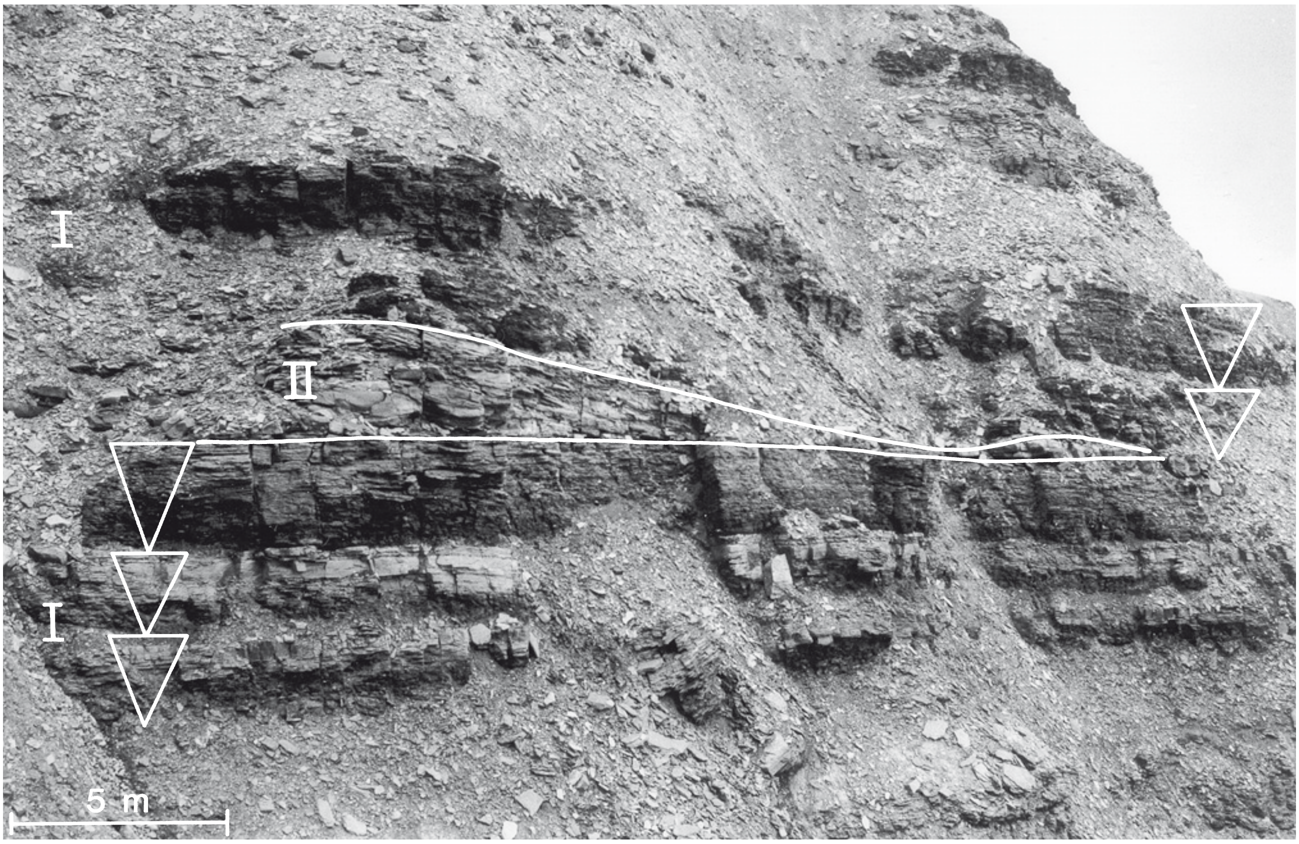


Fig. 26. Ephemeral stream delta lobe sandstones associated with wave and storm-dominated lagoonal deposits. I = stacked wave and storm-dominated lagoonal deposits (Facies association k); II = ephemeral stream delta deposits (Facies association l). Horsedal Member, Horsedal. See Fig. 1 for location.

Leaves, bivalves and concretions with fish remains commonly occur.

Interpretation. The physical structures show features formed by wave and storm action (cf. De Raaf *et al.*, 1977). The internal structures of the thin, fine to medium-grained coarsening-upward units (facies M_2 to S_1 of De Raaf *et al.*, 1977) reflect an increase in wave energy and a shallowing-upward tendency. The low-angle cross-bedded and parallel laminated fine-grained sandstones formed by migration of swash and foreshore ridges on the beach foreshore. The coarsening-upward units represent wave-dominated beaches or bay-head delta systems prograding into an extensive lagoonal environment. A lagoonal environment is supported by the palynomorphs which indicate a freshwater depositional environment (Dam & Koppelhus, in press).

The root-like structures and coal seam couplets represent autochthonous plant remains, formed when the swamp covered the lagoonal delta fronts during delta abandonment. The dichotomous upward-branching of some of the root-like fossils suggests that their upper parts are fossil stems in growth position. The sandy fills indicate that the plants had hollow stems and roots (aquatic plants) and that they grew during sedimentation. Similar plant fossils have been observed in the underlying Kap Stewart Group (Dam, 1991; Dam & Surlyk, 1993), in the Hettangian–Sinemurian Sose Bugt Member of Bornholm, Denmark (Surlyk *et al.*, 1995), and in the Wealden of SE England (Allen, 1981).

l. Ephemeral stream delta association. This association consists of sharply based lenses, with a mound-shaped upper surface, composed of poorly sorted medium to very coarse-grained sandstones. The lenses occur at a single stratigraphic level in Horsedal, associated with wave and storm-dominated lagoonal shoreface deposits (Facies association k; Figs 24, 26). In 2-D sections, the lenses are convex-upward, regularly spaced, and almost isolated from one another. They are up to 4 m thick and thin laterally to less than 25 cm. The distance between the crests of neighbouring lenses range from 75 m to more than 200 m. The sandstones are predominantly cross-bedded, parallel or cross-laminated and form a single fining-upward succession. The lenses are draped by thin form-concordant cross-laminated beds. In one section the basal scoured surface is succeeded by three distinct fining-upward units, 30–150 cm thick, in erosional contact with each other (Fig. 24, IA). Foreset dip directions are generally towards the south, perpendicular to the 2-D sections. The boundary to the overlying mudstones is sharp but non-erosional.

Interpretation. The geometry and poor sorting of the sandstone bodies, and the internal facies arrangement, suggest deposition from unidirectional erosive flows during a single depositional event. The vertical and lateral facies variation within the lenses, and the presence of small erosionally-based fining-upward units, within a major fining-upward succession, reflect highly variable and pulsating hydrodynamic conditions. The sharp, non-erosional contact to the overlying mudstones and the form-concordant bedding suggest that the surface of the 'lenses' represents the original morphology. The palaeocurrent directions indicate a flow direction towards the south, perpendicular to the northern WNW–ESE orientated basin margin, suggesting that the lenses represent cross-sections of small subaqueous lobes that prograded from land into a protected lagoonal environment. The lobes were probably formed during a major flooding event. The flood flow apparently behaved like a plane-jet, scouring the bottom before deposition of the subaqueous ephemeral delta lobes. The form-concordant bedding formed from migrating ripple trains on top of the lobe surface during waning flow.

Fossils. Plant fossils and fish scales are common in concretionary layers. Trace fossils commonly include *Diplocraterion parallelum*, and rare *Arenicolites* isp., *Cochlichnus anguineus, Helminthopsis magna, Lockeia amygdaloides* and *Planolites beverleyensis*.

Boundaries. The lower boundary is placed where cross-laminated and cross-bedded sandstones of the Elis Bjerg Member give way to wave ripple cross-laminated, parallel laminated and hummocky cross-stratified sandstones arranged in small coarsening-upward successions. The Horsedal Member is erosionally overlain by cross-bedded, hummocky cross-stratified and bioturbated sandstones of the Lepidopteriselv Member.

Distribution. The member occurs in Scoresby Land, and in the northern part of Jameson Land where it can be traced as far south as Liaselv. It has not been recorded south of this locality (Fig. 1).

Geological age. None of the recovered body fossils are age diagnostic. Belemnites and ammonites from the overlying Nathorst Fjeld, Lepidopteriselv and Skævdal Members, suggest a Commune Subzone age (the oldest subzone of the Lower Toarcian Bifrons Zone) or even a lowermost Toarcian Tenuicostatum Zone age (Semicelatum Subzone) (Doyle, 1991; J. H. Callomon, personal communication, 1993), suggesting that the Horsedal Member is of Late Pliensbachian age. The member is probably time-equivalent to the Astartekløft Member.

Astartekløft Member

new member

History. Strata included in this member were first described by Rosenkrantz (1934, p. 83, pl. 12, 430–468 m) at Nathorst Fjeld. They form the lower third of the Ostreaelv Member of Surlyk *et al.* (1973) along Neill Klinter, Nathorst Fjeld and Elis Bjerg.

Name. The member is named after the ravine Astartekløft in Neill Klinter in the south-eastern part of the basin (Fig. 1).

Type and reference localities. One of the most well-exposed and complete developments of the member occurs in Astartekløft and is designated the type locality. Well-exposed reference sections occur at Nathorst Fjeld, where the member forms an almost vertical cliff section, Harris Fjeld and along Neill Klinter at Moskusoksekløft, Goniomyakløft, Albuen and Qupaulakajik (Figs 1, 27, 28).

Thickness. The member is 25 m thick at the type section, 18–43 m along Neill Klinter, and 29 m at Nathorst Fjeld.

Lithology. Along Neill Klinter the member consists of cross-laminated and cross-bedded sandstones alternating with thin mudstone beds, similar to the Elis Bjerg Member. Plant fragments are common, and logs and belemnites occur occasionally. At Nathorst Fjeld the member consists of medium to very coarse-grained cross-bedded sandstones, which pass upward into medium-grained bioturbated sandstones with bivalves and crinoids.

Facies associations and depositional environments. Along Neill Klinter the member includes four facies associations (f, g, h and m). They are very similar to the analogous facies associations of the Elis Bjerg Member and are designated as such. However, they are described separately in this section. The tidal channel succession which occurs at Nathorst Fjeld has a very different character from the tidal channel successions otherwise recognised in the Gule Horn Formation and Astartekløft Member and is therefore treated separately.

f. Subtidal sand sheet association. This association is characteristic of the member all along Neill Klinter in the south-eastern part of the basin. It consists of sandstone beds and alternating laminated and thinly bedded mudstones and sandstones arranged in a single coarsening-upward or several smaller coarsening or fining-upward successions (Fig. 27).

The sandstones occur in planar and trough cross-bedded medium to very coarse-grained beds with scattered plant fragments and logs. Each set is 10–145 cm thick and has tangential foresets. Thin single mudstone drapes and mudstone clasts commonly occur along foresets. They flatten out along toesets and extend downward into heterolithic beds. Reactivation surfaces are common and occasionally they are capped by cross-laminated sandstones showing a foreset dip direction in the opposite direction to the master bedding. The cross-bedded sets are generally separated by thin heterolithic beds, 10–35 cm thick. Bedding planes may show lunate current ripples and occasionally wave ripples. Cone-in-cone structures are common in the heterolithic beds. The sandstones are characterised by elements of the *Diplocraterion* ichnocoenosis and the heterolithic beds include elements of the *Cochlichnus* ichnocoenosis of Dam (1990b). Trace fossils include common *Curvolithos multiplex, Diplocraterion parallelum, Gyrochorte comosa, Ophiomorpha nodosa, Phoebichnus trochoides, Planolites beverleyensis, Taenidium serpentinum, Teichichnus* isp. and *Rhizocorallium* isp.

Combined palaeocurrent data show bipolar directions toward SSW and NNE indicating reversing currents. The dominant direction is towards SSW.

Interpretation. The presence of mudstone drapes, reactivation surfaces capped by cross-laminated sandstones, bipolar palaeocurrent directions, and lack of any indications of subaerial exposure indicate that the sandstones were deposited as migrating small and medium-scale subtidal dunes in a strong subtidal current regime (e.g. Boersma, 1969, Visser, 1980). The presence of elements of the *Diplocraterion* ichnocoenosis suggests a high-energy, shallow subtidal to intertidal environment (Fürsich, 1975).

The presence of heterolithic beds between the cross- bedded sandstones suggests that these represent inter-dune areas. The trace fossil assemblage of the heterolithic beds reflects a wide variety of feeding habits and behavioural categories, indicating a well-aerated medium to low-energy shallow marine environment, with abundant food supply for both suspension and deposit-feeders, and mobile carnivores (Dam 1990b).

g. Tidal channel association. This association is characteristic of the member at Albuen (Fig. 27). It consists of fining and thinning-upward successions, up to 8.5 m thick. The successions are bounded by a lower erosion surface, commonly draped by a lag conglomerate composed of mudstone and sandstone intraclasts. The conglomerate is overlain by coarse-grained sandstones with distinct trough and planar cross-bedded cosets, with set heights decreasing upwards from 90 cm to 20 cm. The sets may be separated by thin mudstone layers. Scattered mudstone clasts are common in the sandstones. Foreset dip directions are unimodal towards west, in a basinwards direction. The upper parts of the successions show an upward increase in number of intercalated mudstone layers, and the cross-bedded sandstones grade into bioturbated flaser, wavy and lenticular-bedded heteroliths. The heterolithic deposits are commonly extensively burrowed by *Arenicolites* isp., *Diplocraterion parallelum* and *Rhizocorallium* isp., elements of the *Diplocraterion* ichnocoenosis of Dam (1990b).

Interpretation. The distinct fining-upward units were formed by lateral migration of channels. The base of the units was formed by erosion along the active channel thalweg. The succeeding cross-bedded cosets were formed by 2-D and 3-D small-scale dunes migrating on the channel floor. The upper heterolithic parts of the successions were deposited along the inner bend of the channel. The lack of any clear tidal characters are interpreted as reflecting deposition in intertidal channels. Some tidal influence is, however, suggested by the presence of mudstone layers separating individual sets. They were probably deposited during slack-water stages. The trace fossil assemblage indicates a high-energy, shallow subtidal to intertidal environment (cf. Fürsich, 1975).

h. Storm-dominated sandy shoal association. This association is characteristic of the Astartekløft Member at Albuen (Fig. 27). It consists of amalgamated fine to medium-grained sharply-based sandstone beds closely associated with tidal channel deposits. Each bed is 15–110 cm thick and forms an amalgamated bed-set, 4.8 m

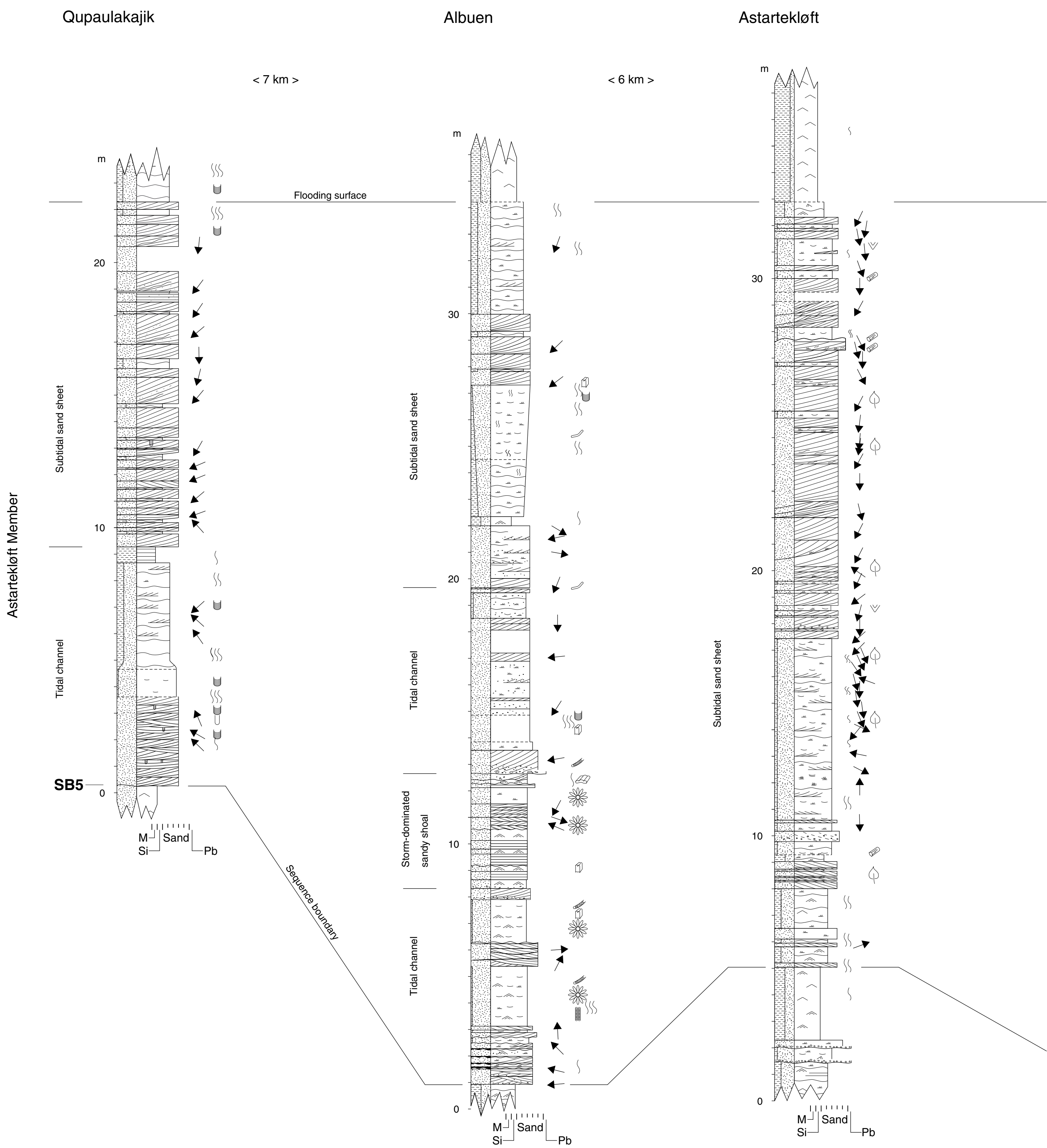
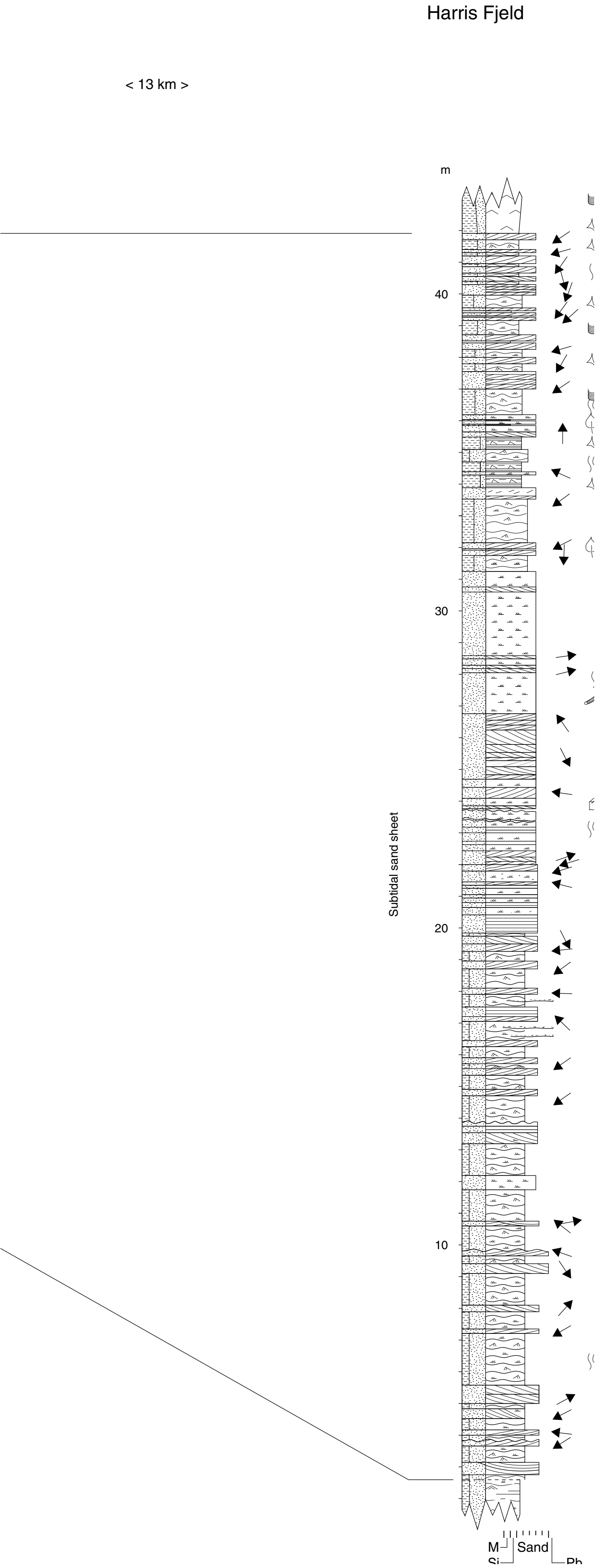


Fig. 27. Sedimentological log through the tidal channel, subtidal sand sheet and storm-dominated sandy shoal deposits of the Astartekløft Member. See Fig. 1 for locations and Plate 1 for legend. Modified from Dam & Surlyk (1995).



thick. Internally the sandstones are parallel-laminated, grading upward into wave ripple cross-lamination. Some beds may show cross-bedding with scattered mudstone clasts. The sandstones are bioturbated weakly to heavily by *Gyrochorte comosa, Ophiomorpha nodosa, Phoebichnus trochoides, Planolites beverleyensis, Taenidium serpentinum*, and elements of the *Planolites* and *Taenidium* ichnocoenoses (Dam, 1990b).

Interpretation. The sharp bases of sandstone beds and the dominance of parallel lamination suggest episodic deposition from waning flows characterised by combined flow-processes or intense bed shear due to storm-wave activity. The cross-laminated tops were formed during decelerating flow. The interbedding with tidal channel deposits suggests that the successions represent storm-dominated shoals. The *Planolites* and *Taenidium* ichnocoenoses are very characteristic of deposits of storm-dominated environments in the Neill Klinter Group, and indicate that between storm events, periods of low-energy and oxygen-limitation prevailed in the substratum.

m. Tidal channel association. This association is characteristic of the Astartekløft Member at Nathorst Fjeld. It consists dominantly of planar and elongate trough cross-bedded medium to very coarse-grained sandstone (Fig. 28), and less commonly of bioturbated, parallel and cross-laminated sandstones. Set thickness varies from 0.2 to 2.9 m. Foresets are tangential and dip angles range from 17 to 30°. Logs and plant fragments occur in the basal part of the sets. The cross-bedded sets form a coset, 29 m thick, with thinning upward set thicknesses (Fig. 28). The lower surface of the cosets may be erosional. The foresets dip unimodally towards the west.

In the upper part of the succession the sandstones are commonly burrowed by *Curvolithos multiplex, Diplocraterion habichi, Gyrochorte comosa, Ophiomorpha nodosa*, and *Taenidium serpentinum*, and fragments of the crinoid *Pentacrinus* are common.

Interpretation. The cross-bedded sandstones were deposited by extensive fields of migrating small and medium-scale 2-D and 3-D dunes. The lower erosional boundary of the succession, the general offshore directed currents, the upward thinning of set thickness and the body and trace fossil fauna suggest deposition in the subtidal parts of a tidal channel.

Boundaries. The boundary between the muddy deposits of the underlying Albuen Member and the cross-bedded sandstone of the Astartekløft Member is erosional along Hurry Inlet (Fig. 27). At Nathorst Fjeld

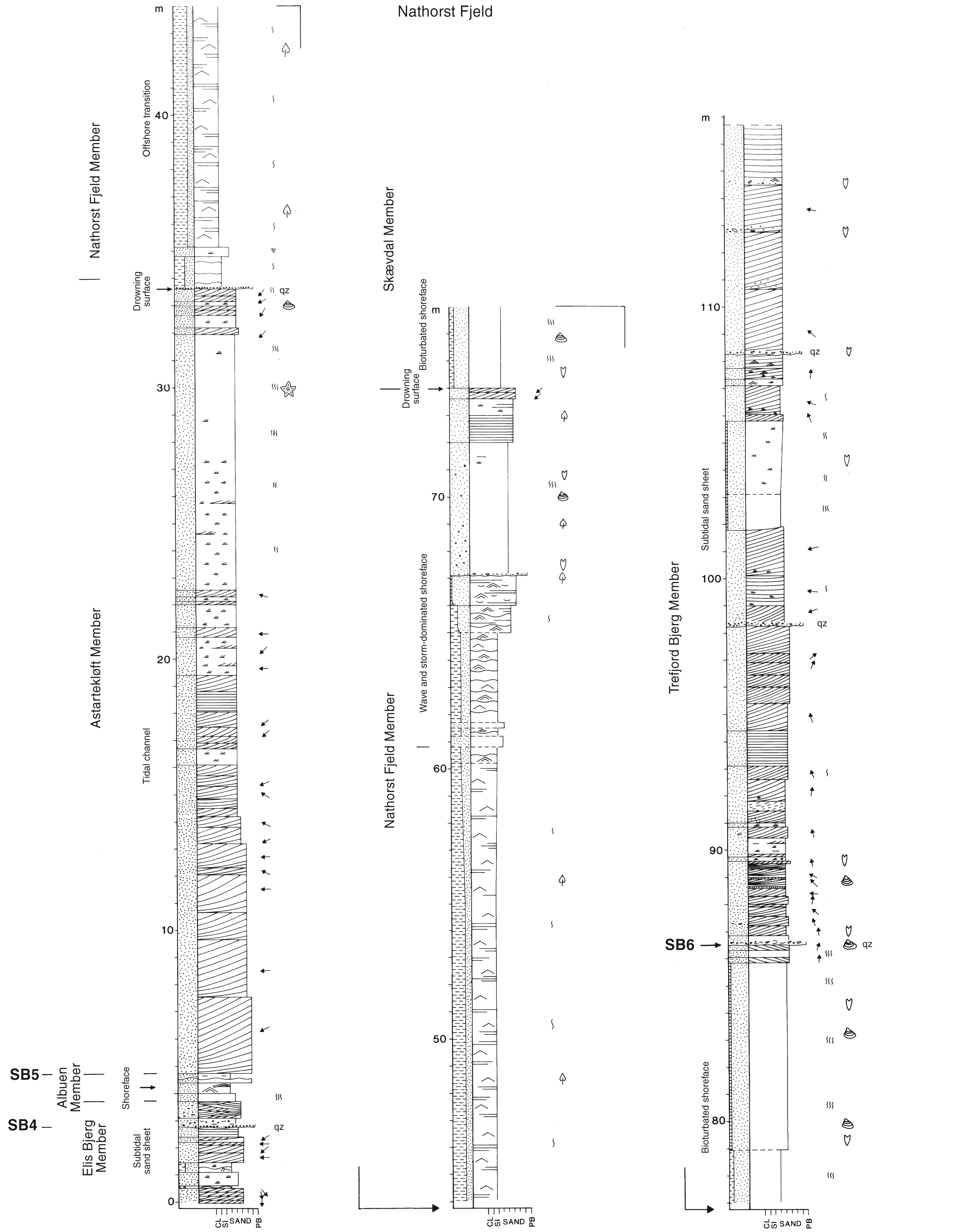


Fig. 28. Sedimentological log through the Astartekløft, Nathorst Fjeld, Skævdal and Trefjord Bjerg Members at Nathorst Fjeld. See Fig. 1 for location and Plate 1 for legend.

Fig. 29. Thin lag conglomerate separating tidal channel sandstones of the Astartekløft Member from offshore transition deposits of the overlying Nathorst Fjeld Member at Nathorst Fjeld. See Fig. 1 for location. The conglomerate consists of well-sorted, well-rounded quartzitic pebbles with a maximum diameter of 3 cm. The sandstone just below the conglomerate is strongly burrowed by *Diplocraterion parallelum*.

and Elis Bjerg the lower boundary is sharp and erosional (Fig. 28). The upper boundary between the sandstones of the Astartekløft Member and the silty mudstones of the laterally correlative Nathorst Fjeld and Harris Fjeld Members is sharp and at Nathorst Fjeld a conglomerate of extraformational pebbles, 3 cm thick, separates the members (Figs 28, 29).

Distribution. The member occurs along the length of Neill Klinter and as far north as Dusén Bjerg.

Fossils. The member has only yielded a few belemnites, oysters and crinoids. Trace fossils include common *Arenicolites* isp. 2 (Dam, 1990a) and rare *Curvolithos multiplex, Diplocraterion habichi, Gyrochorte comosa, Ophiomorpha nodosa*, and *Taenidium serpen-*

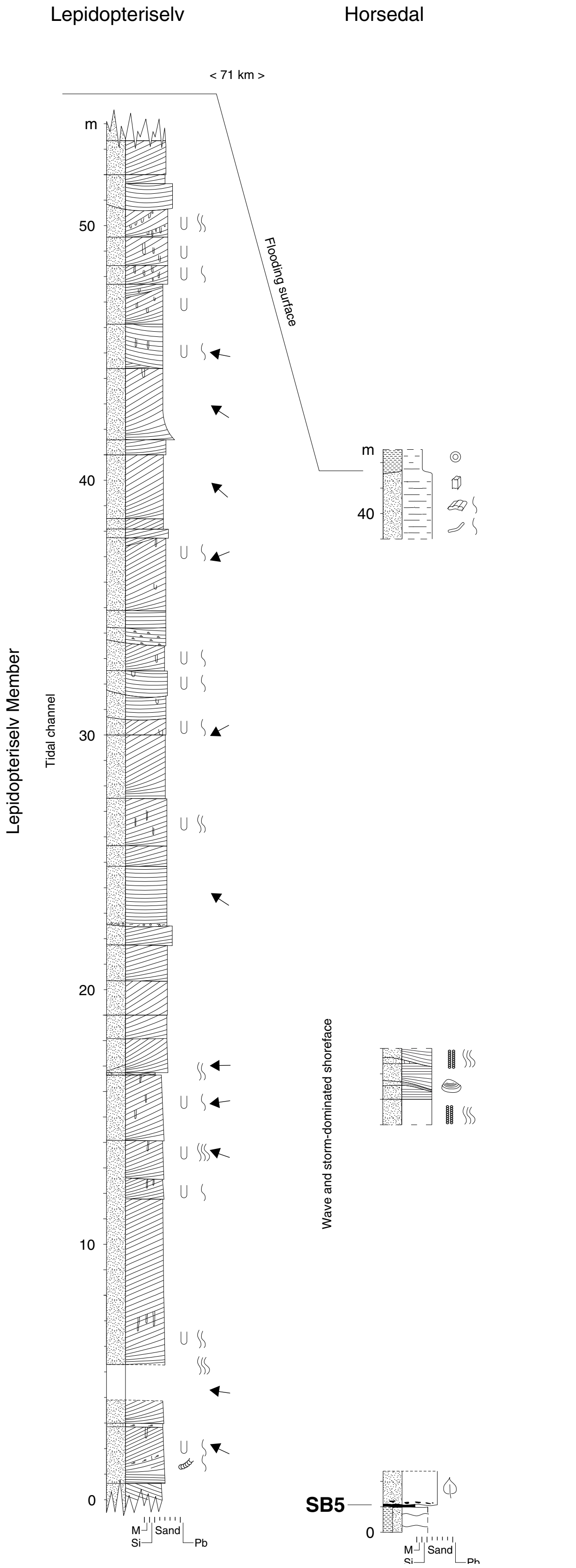


Fig. 30. Sedimentological logs through the Lepidopteriselv Member at Lepidopteriselv and Horsedal. See Fig. 1 for locations and Plate 1 for legend.

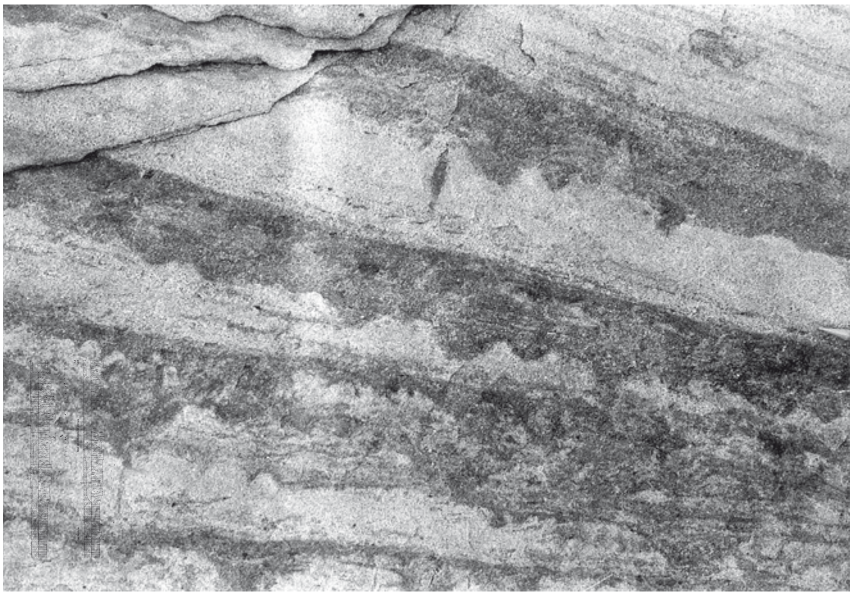


Fig. 31. Resting traces on foresets of cross-bedded sandstones of the tidal channel association (m). Lepidopteriselv Member, Lepidopteriselv. See Fig. 1 for location.

tinum. Resting traces and polychaete burrows also occur.

Geological age. None of the body fossils are age diagnostic. Dinoflagellate cysts from the base of the member suggest an early Toarcian age (Koppelhus & Dam, in press).

Lepidopteriselv Member

new member

History. North of Nathorst Fjeld the Lepidopteriselv Member constitutes the lower third of the Ostreaelv Member of Surlyk *et al.* (1973).

Name. The member is named after the river Lepidopteriselv in north-eastern Jameson Land (Fig. 1).

Type and reference localities. One of the most complete developments of the member is well-exposed at Lepidopteriselv, where it forms an almost vertical cliff section. This is designated the type section. Well-exposed reference sections occur at Liaselv, in Horsedal and Ranunkeldal (Figs 1, 30).

Thickness. The member is 60 m thick at Lepidopteriselv and 48 m at Horsedal.

Lithology. At the type section the Lepidopteriselv Member is cliff-forming and consists of medium to coarse-grained, cross-bedded, glauconitic sandstones. At Elis Bjerg cross-bedded sandstones pass laterally into medium-grained bioturbated sandstones with bivalves, belemnites, ammonites and crinoids. At Liaselv and in Horsedal the cross-bedded sandstones alternate with fossiliferous, clean, bioturbated, cross-bedded and hummocky cross-stratified fine to medium-grained sandstones.

Facies associations and depositional environments. The member includes three facies associations (m, n an d o).

m. Tidal channel association. This association is characteristic of the Lepidopteriselv Member at Lepidopteriselv, and is very similar to the Nathorst Fjeld Member at Nathorst Fjeld and the Trefjord Bjerg Member at Lepidopteriselv. It dominantly consists of a planar and elongate trough cross-bedded medium to coarse-grained glauconitic sandstone unit (Fig. 30), but cross-laminated beds also occur. In the Lepidopteriselv area the thickness of the member varies from 55 to 80 m. The lower surface of the sandstone unit is not exposed, but from the thickness variations of the member in the area it seems that the sandstones are separated from the heterolithic deposits of the Elis Bjerg Member below by a major erosional surface. The upper boundary to the bioturbated muddy sandstones of the Skævdal Member is flat and non-erosional. Set thickness of the cross-bedded sets varies from 0.35 to 6.5 m. Foresets are tangential and dip angles range from 21 to 31°. The foresets dip unimodally towards the west. Thin mudstone drapes may occur in couplets on the foresets, and enclose a thin sandstone layer displaying cross-lamination with a foreset orientation opposite to that of the cross-bedding. Groups of foresets may form bundle sequences (cf. Visser, 1980).

The cross-bedded sandstones are commonly burrowed by *Arenicolites* isp. 2. (Dam, 1990a). Resting traces may occur along foresets of the cross-bedded sandstones, and may have, together with polychaete burrows, completely mottled the bottomsets (Fig. 31). *Arenicolites* isp. 2 lacks a burrow lining and shows a great morphological variability (Dam, 1990a).

A single conglomeratic bed, 2 m thick, occurs on the northern slope of Elis Bjerg. It consists of subrounded quartz pebbles with a diameter of 5 to 30 mm, in a matrix of coarse to very coarse-grained sand. The conglomerate is weakly parallel laminated and cross-bedded.

Interpretation. The cross-bedded sandstones were deposited by extensive fields of migrating small and medium-scale 2-D and 3-D dunes. The presence of mudstone couplets and foreset bundles indicates that deposition took place in a subtidal environment with an ordinate and a subordinate current (Visser, 1980). Foreset dip directions towards the west indicate a basinward flow direction. The lower erosional surface of the cross-bedded sandstone unit and the general offshore directed flow directions suggest deposition in the subtidal parts of a tidal channel. The *Arenicolites* isp. 2 ichnocoenosis represents a low diversity assemblage of organisms that adapted themselves to well-aerated high-energy environments of great physical instability. The lack of burrow linings, great morphological variability and scattered distribution suggest that *Arenicolites* isp. 2 must have acted as shelters for only a short period of time and not as permanent domiciles, indicating a high sediment influx (Dam, 1990a, b).

n. Wave and storm-dominated shoreface association. This association constitutes the Lepidopteriselv Member in the northern part of the basin. It consists of single or amalgamated beds of cross-bedded, parallel laminated, hummocky and swaley cross-stratified very fine to fine-grained sandstones (Fig. 30). The beds have flat, sharp and erosional bases. Abundant transported bivalves and crinoids are common in the laminae, and include *Astarte* sp., *Corbicellopsis unioides, Modiolus (Strimodiolus) elongatus, Pleuromya uralensis* and *Pentacrinus* sp. The sandstones are commonly burrowed by *Ophiomorpha nodosa*. Bioturbated very fine to fine-grained sandstones, 0.1–1 m thick, occur interbedded with the parallel laminated, hummocky and swaley cross-stratified sandstones.

Interpretation. The sharp bases of individual sandstone beds and the dominance of parallel lamination suggest episodic deposition from waning flows characterised by combined flow-processes or intense bed shear due to storm-wave activity. Hummocky cross-stratification is formed by aggradation or translation in a combined or oscillatory flow regime (Dott & Bourgeois, 1982; Swift *et al.*, 1983; Allen, 1985; Surlyk & Noe-Nygaard, 1986). Amalgamation of beds is caused by scouring and erosion above storm-wave base with the removal of the fine-grained, bioturbated caps (Dott & Bourgeois, 1982; Leithold & Bourgeois, 1984). The interbedding with heavily bioturbated, wave ripple laminated sandstones suggest deposition at or just below fair-weather wave-base and above storm wave-base. The transported bivalves include both shallow and deep burrowing forms, the latter indicating that deep erosion frequently occurred on the shoreface during storms (cf. Fürsich, 1982, 1984).

The *Ophiomorpha* ichnocoenosis of the storm-deposited sandstones indicates moderate to high sedimentation rates and a low rate of reworking as shown by the complex clay-ball-lined walls (Heinberg & Birkelund, 1984). The occurrence of only *Ophiomorpha* in amalgamated sandstones indicates physically unstable conditions (i.e. high storm frequency) favouring opportunistic behaviour (Rhoads *et al.*, 1985; Vossler & Pemberton, 1989).

o. Bioturbated shoreface association. This association is characteristic of the Lepidopteriselv Member at Elis Bjerg, Liaselv and in Horsedal. The association consists of bioturbated fine to medium-grained sandstones, locally containing phosphate nodules. It may form thoroughly bioturbated successions, more than 10 m thick, laterally intercalated with tidal channel and storm-dominated inner shelf deposits (Facies associations m and n). Primary physical structures include wave ripples, hummocky cross-stratification, cross-bedding and cross-lamination.

The bioturbated deposits are characterised by the *Curvolithos* ichnocoenosis dominated by *Curvolithos multiplex*, but also include common *Thalassinoides* isp., *Ophiomorpha nodosa, Rhizocorallium irregulare, Gyrochorte comosa, Planolites beverleyensis, Arenicolites* isp. 1 (Dam, 1990a), *Diplocraterion parallelum* and *Palaeophycus* isp. and rare *Cruziana* isp. and *Taenidium serpentinum* (Dam, 1990a, b). Belemnites and bivalves are common.

Interpretation. The high degree of bioturbation and the general scarcity of preserved physical structures indicate a relatively slow sedimentation rate, little physical reworking and abundant food supply. The *Curvolithos* ichnocoenosis reflects a diverse fauna of infaunal and epifaunal suspension and deposit-feeding organisms, as well as carnivores. The trophically diverse fauna lived in a well-aerated environment (Dam, 1990b). Phosphatic concretions probably formed within the anoxic zone just below the sediment-seawater interface during low sedimentation rates (cf. Cook, 1976; O'Brien, 1990).

Boundaries. At the type locality and at Horsedal the sandstones of the Lepidopteriselv Member rest with a sharp, erosional lower boundary on the heterolithic deposits of the Astartekløft and Horsedal Members, respectively. The upper boundary is placed at the sharp lithological change from sandstones of the Lepidopteriselv Member to the muddy bioturbated sandstones of the Skævdal Member.

Fossils. Fossils are common in the member and include bivalves, crinoids, belemnites and ammonites. The ammonites were found at Elis Bjerg and Horsedal and include *Dactylioceras semicelatum* (Simpson) (also including *D. groenlandicum* Rosenkrantz 1934) and *Hildaites* sp. aff. *H. murleyi* (Moxon) (J. H. Callomon, personal communication, 1993). Those collected in Horsedal were found loose.

Distribution. The member occurs north of Nathorst Fjeld and in Ranunkeldal in the north-western part of the basin.

Geological age. The ammonite *Dactylioceras semicelatum* indicates an Early Toarcian, Tenuicostatum Zone, Semicelatum Subzone age of the Lepidopteriselv Member (J. H. Callomon, personal communication, 1993).

Nathorst Fjeld Member

new member

History. The strata composing this member were first described by Rosenkrantz (1934, p. 83, pl. 12). Along Neill Klinter and at Nathorst Fjeld the member represents the middle part of the Ostreaelv Member of Surlyk *et al.* (1973).

Name. The member is named after the mountain Nathorst Fjeld in the south-eastern part of Jameson Land (Fig. 1).

Type and reference localities. The member is well-exposed at Nathorst Fjeld which is designated the type section. Reference sections occur at Moskusoksekløft, Astartekløft and Albuen (Figs 1, 32).

Thickness. The member is 30 m thick at the type section, 35 m at Moskusoksekløft, 37 m in Astartekløft, and 29 m at Albuen.

Lithology. The member forms a single coarsening-upward unit consisting of alternating silty mudstones and thin laminae of very fine to fine-grained sandstones, grading upward into fine to coarse-grained sandstones. The sandstones are trough and planar cross-bedded, wave ripple cross-laminated and cross-bedded, hummocky cross-stratified or bioturbated. Highly disintegrated plant remains and cone-in-cone structures are common in the silty mudstones and very fine to fine-grained sandstones. Thin conglomerates with mud chips, body fossils, quartzite pebbles and plant remains occur at several levels in the fine to coarse-grained sandstones.

Facies associations and depositional environments. The member comprises two facies associations (p and q).

p. Offshore transition association. This association is characteristic of the lower part of the member, and consists of silty mudstones, forming a homogeneous unit up to 30 m thick, with very fine and fine-grained micaceous sandstone streaks (Fig. 32). The streaks show pinch and swell structures, incipient lenses and parallel lamination grading into wave ripple cross-lamination (cf. Facies M_1 of De Raaf *et al.*, 1977). The streaked mudstones locally contain comminuted plant debris, early diagenetic phosphatic concretions and calcareous concretionary layers with cone-in-cone structures. The mudstones are commonly burrowed by *Curvolithos multiplex* and *Planolites beverleyensis*.

Interpretation. The streaked mudstones were deposited from suspension in an offshore transition environment with restricted wave activity. The phosphatic concretions probably formed within the anoxic zone just below the sediment-seawater interface during low sedimentation rates (cf. Cook, 1976; O'Brien *et al.*, 1990).

q. Shoreface association. This association consists of a coarsening-upward succession, 13–24 m thick, present in the upper part of the member (Fig. 32). It has a lateral extent of several tens of kilometres. The lower part of the succession is lenticular and wavy bedded.

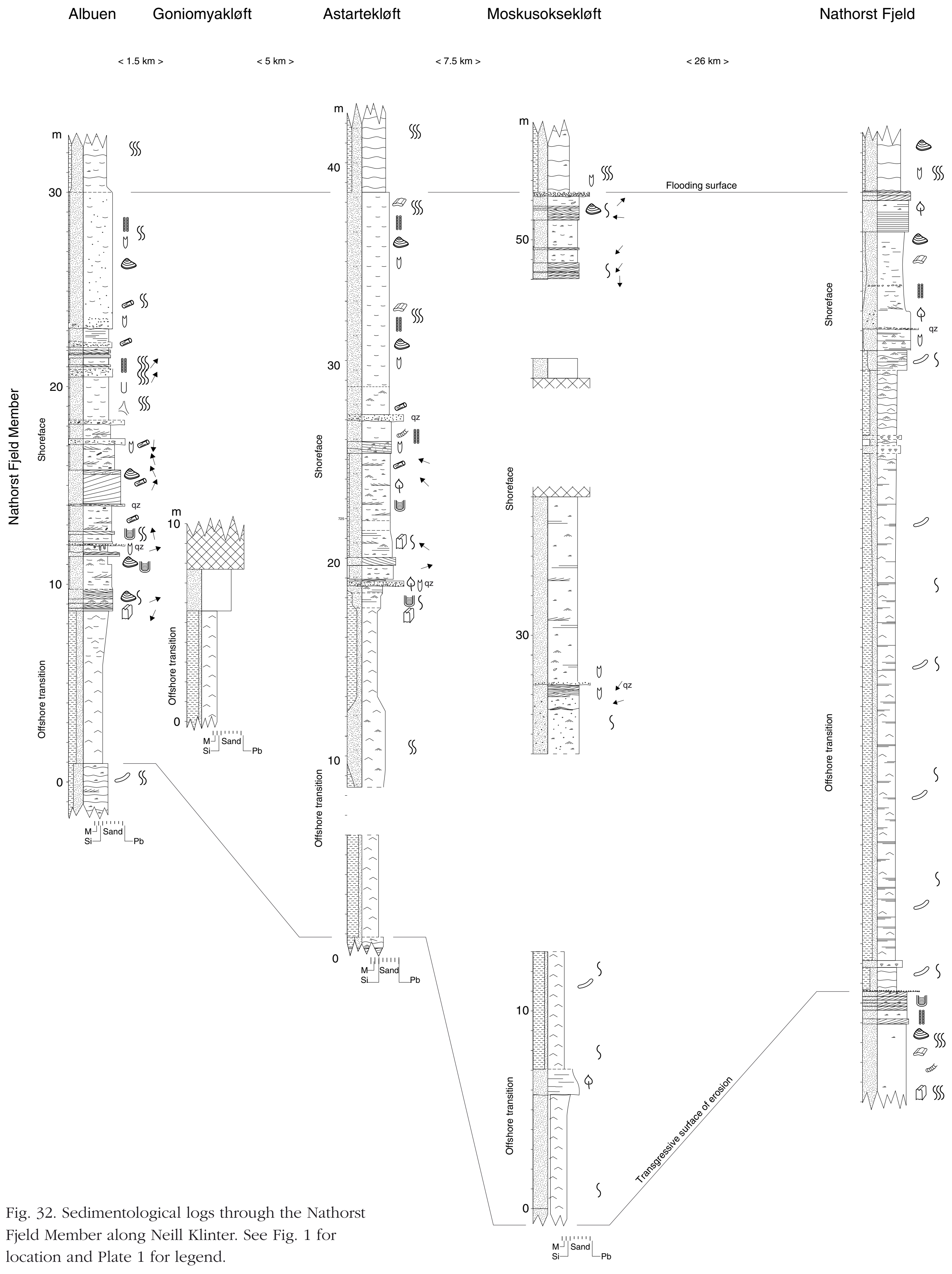


Fig. 32. Sedimentological logs through the Nathorst Fjeld Member along Neill Klinter. See Fig. 1 for location and Plate 1 for legend.

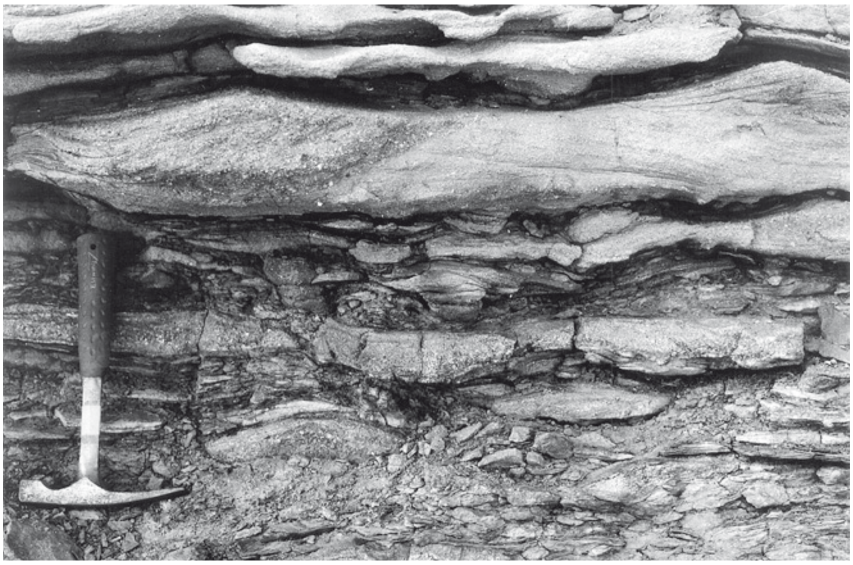


Fig. 33. Coarse-grained symmetrical ripples showing features characteristic of wave-formed ripples of the shoreface association (q) of the Nathorst Fjeld Member. Nathorst Fjeld. See Fig. 1 for location. Hammer 32 cm long.

It is erosionally overlain by poorly-sorted medium to very coarse-grained sandstones comparable to the sandstones of the Rævekløft Formation, and very fine to fine-grained sandstones. Well-rounded quartzitic pebbles, logs, plant remains and transported assemblages of bivalves and belemnites, commonly occur scattered in the medium to very coarse-grained sandstones or form thin laterally extensive conglomerates, less than 20 cm thick. The sandstones are planar and trough cross-bedded, parallel laminated or massive. The cross-bedded sets occur singly or more commonly in cosets. Set thickness varies from 0.1 to 1.5 m. The foreset dip directions are generally towards NNE and SW, but show a large scatter. Cross-bedded medium to coarse-grained sandstones also occur, and show features characteristic of wave action, such as irregular lower boundaries, opposed unidirectional cross-bedded lenses, offshooting and draping laminations, symmetrical ripple form sets (Fig. 33), similar to those of the wave and storm-dominated shoreface deposits of the Elis Bjerg Member (Facies association e). Wave lengths and amplitudes of the symmetrical ripples are 50–60 cm and 6–10 cm, respectively, and dominant crest line orientations are E–W and N–S.

The massive sandstones are strongly bioturbated and occur in beds 0.25–5.5 m thick. The sandstones contain elements of the *Curvolithos* ichnocoenosis including abundant *Curvolithos multiplex, Ophiomorpha nodosa, Taenidum serpentinum, Thalassinoides* isp., common *Arenicolites* isp., *Diplocraterion parallelum*, and rare *Rhizocorallium irregulare* (Dam, 1990b). The top of the sandstones are commonly burrowed by *Skolithos* isp. and *Arenicolites* isp.

The very fine to fine-grained sandstones show parallel lamination and hummocky cross-stratification. The upper part of the sandstones may be glauconitised and a thin lag conglomerate occasionally occurs on top of the succession.

Interpretation. The coarsening-upward succession reflects an increase in energy with time and is interpreted as a shallowing-upward succession. The cross-bedded sandstones are interpreted as representing fields of small-scale 2-D and 3-D dunes migrating longshore towards NNE and SSW on the upper shoreface. The apparent bimodality of the palaeocurrents is the only suggestion of tidal activity and no other tidal features occur. It is thus more likely that the bimodality represents local reversals of the coast-parallel current system. The cross-bedded sandstones showing features characteristic of wave action is interpreted as representing fields of large symmetrical ripples on the shoreface similar to those recorded from modern shoreface and offshore transition settings formed by oscillatory or oscillatory-dominant flows (cf. Newton & Werner, 1972; Cacchione *et al.*, 1984; Hunter *et al.*, 1988; Leckie, 1988). Hummocky cross-stratification formed during storms by aggradation or translation in a combined or oscillatory flow regime (Dott & Bourgeois, 1982; Swift *et al.*, 1983; Allen, 1985; Surlyk & Noe-Nygaard, 1986). The thin conglomerates interbedded with the sandstones were probably transported during storms or winnowing during periods of non-deposition.

The *Curvolithos* ichnocoenosis reflects prolonged periods of well-aerated conditions, intermediate energy and slow deposition (Dam, 1990b).

Fossils. Several thin, fossiliferous levels occur in the upper part of the member and contain bivalves, brachiopods, ammonites, belemnites, crinoids and vertebrates. Fossils collected at Nathorst Fjeld were listed by Rosenkrantz (1934, p. 82–84, 494–511 m) and include the belemnite *Megateuthis* sp. and the ammonite *Dactylioceras* sp. Trace fossils include common occurrences of *Arenicolites* isp., *Curvolithos multiplex, Diplocraterion parallelum, Gyrochorte comosa, Ophiomorpha nodosa, Planolites beverleyensis, Rhizocorallium irregulare, Taenidium serpentinum* and *Thalassinoides* isp.

Boundaries. The lower boundary is sharp and is marked by the change from the sandstones of the Astartekløft Member to the alternating mudstones and thinly laminated sandstones of the Nathorst Fjeld Member. At Nathorst Fjeld the boundary is marked by a very thin pebble conglomerate (Fig. 29). The upper boundary is also sharp and is marked by a change from the sandstones of the Nathorst Fjeld Member to the bioturbated sandy mudstones of the Skævdal Member.

Distribution. The member occurs along the length of Neill Klinter and at Nathorst Fjeld.

Geological age. At his locality 2 at Nathorst Fjeld, Rosenkrantz (1934) collected a specimen of the belemnite *Parapassolotheuthis polita* (Simpson, 1866) at an altitude of 494 m, and of '*Parabrachybelus*' *subaduncatus* (Voltz, 1930) at 509 m (Doyle, 1991).

Although there is a discrepancy in altitude the lithological descriptions of Rosenkrantz (1934), suggest that the level with *P. polita* belongs to the upper part of the Nathorst Fjeld Member and the level with *'P.' subaduncatus* to the overlying Skævdal Member. The two species have restricted ranges and are not known to be widespread in Europe. *P. polita* is only recorded from the lower Toarcian latest Falciferum Zone or lowermost Bifrons Zone (Commune Subzone) in Britain, while *'P.' subaduncatus*, so far recorded only from mainland Europe, has a range probably restricted to the uppermost Toarcian Levesquei Zone (Doyle, 1991).

The ammonite *Dactylioceras semicelatum* (Simpson) has been collected at the base of the Skævdal Member at Nathorst Fjeld (C. Bjerrum, personal communication, 1996) and in the Lepidopteriselv Member on top of Elis Bjerg indicating an Early Toarcian Tenuicostatum Zone, Semicelatum Subzone age (J. H. Callomon, personal communication, 1993). Sequence stratigraphically the Nathorst Fjeld Member is correlated with the Lepidopteriselv Member. This discrepancy in the age of the two members may indicate that *P. polita* cannot be used stratigraphically, or that the *D. semicelatum* at the base of the Skævdal Member is reworked. Palynomorphs suggest an Early Toarcian age of the Nathorst Fjeld Member (Koppelhus & Dam, in press).

Harris Fjeld Member

new member

History. Strata referred to the Harris Fjeld Member were included in the Ostreaelv Member by Surlyk *et al*. (1973). Deposits from the unit were figured in Sykes (1974, pl. 4, fig. 1).

Name. The member is named after the mountain Harris Fjeld at Hurry Inlet, south-eastern Jameson Land (Fig. 1).

Type locality. The member is only known from Harris Fjeld (Fig. 1).

Thickness. The member is 34–40 m thick.

Lithology. The Harris Fjeld Member consists of tabular, heterolithic or sandy clinoform beds, up to 18 m thick, that laterally pass into silty shales and cross-bedded sandstones.

Facies associations and depositional environments. The member is mainly made up of the ebb-tidal delta Facies association (r). However, minor occurrences of subtidal sand sheet (Facies association f) and offshore transition deposits (Facies association p) also occur.

r. Ebb-tidal delta association. This association includes the largest sedimentary structures identified in the Neill Klinter Group, and is characteristic of the Harris Fjeld Member. The association consists of tabular, low-angle clinoform beds, 6–21 m thick (Figs 34–37). The clinoforms are tangential and dip 5–15° basinwards towards west. The beds can be followed for 2 km along strike and pass laterally into offshore transition mudstones or shoreface sandstones of the Nathorst Fjeld Member (Facies associations p and q). The clinoform beds gradually overlie silty shales or cross-bedded sandstones of the subtidal sand sheet association (Facies association f). The upper boundary is sharp and erosional and is succeeded by restricted shelf mudstones of the Skævdal Member (Figs 34–37).

The clinoform beds are either heterolithic (Fig. 35)

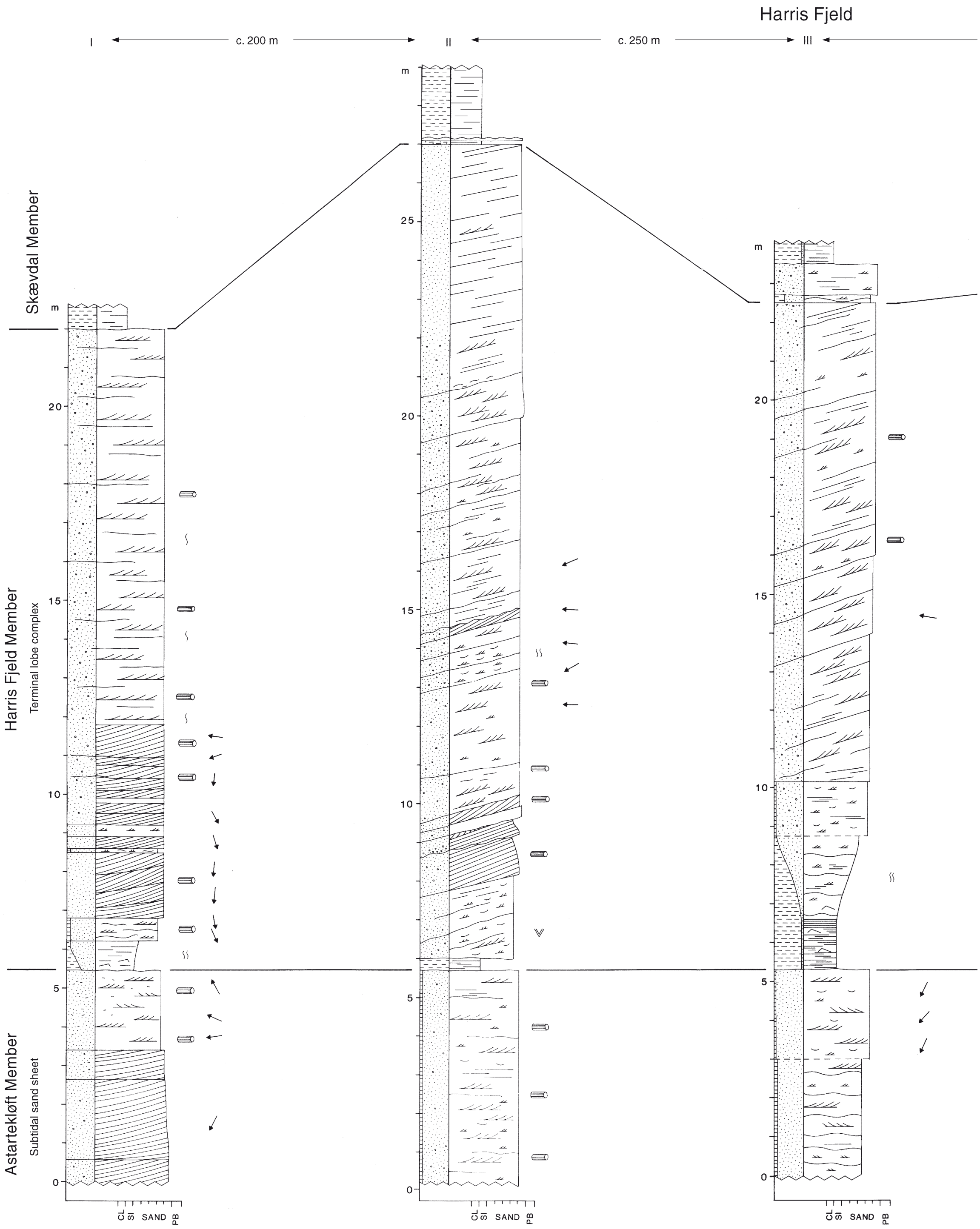
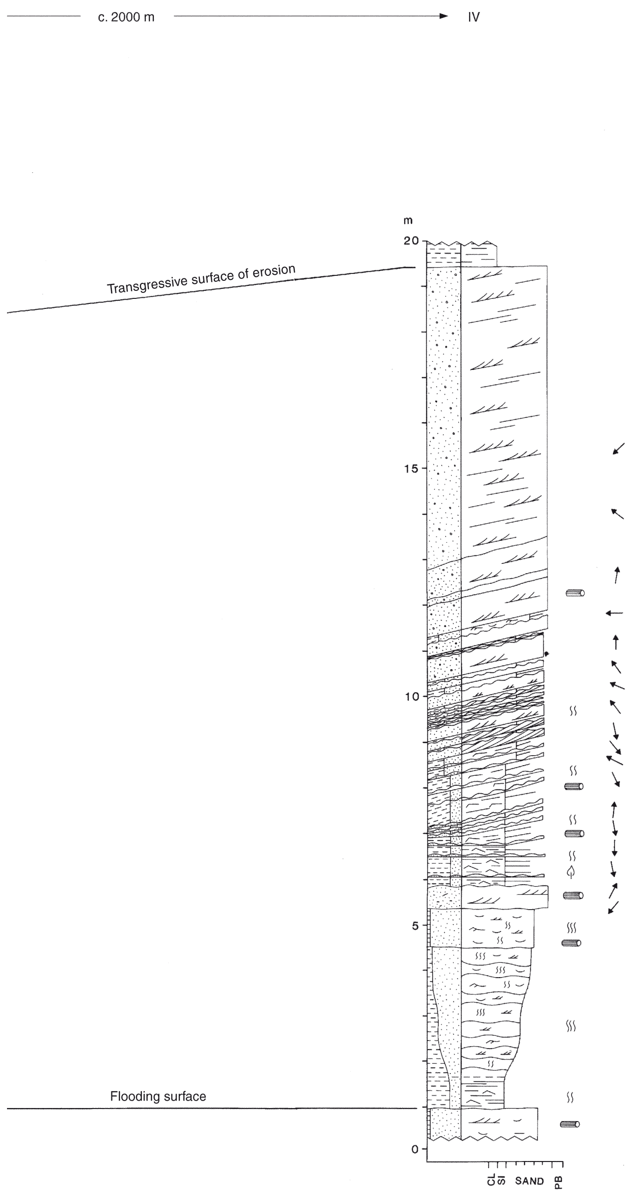


Fig. 34. Sedimentological logs through the Harris Fjeld Member at Harris Fjeld. See Fig. 1 for location and Plate 1 for legend.



or sandy throughout (Figs 36, 37). The heterolithic beds consist of alternating mudstone layers and planar and trough cross-bedded sandstone intrasets. The intrasets are 5–35 cm thick. Mudstone drapes and mudstone intraclasts are common on the foresets of the intrasets. The thickness of the intrasets decreases down-dip, whereas the thickness of mudstone layers increases, resulting in the overall coarsening-upward pattern seen in vertical sections. The foreset dip direction of the intrasets in the upper part of the heterolithic sets is parallel to the dip direction of the clinoforms. Along the toe of the clinoforms the dip directions of the intrasets are perpendicular to the dip direction of the clinoforms. Trace fossils are rare and only occur along the toe of the clinoforms, but include elements of the *Cochlichnus* ichnocoenosis (Dam, 1990b).

The sandy clinoform beds consist of alternations of coarser and finer structureless beds, 5–25 cm thick. Continuous mudstone laminae and intrasets commonly occur. Simple avalanche foresets showing inverse grading have not been recorded. A lateral transition from the sandy to the heterolithic clinoform beds occurs from south to north at Harris Fjeld (Fig. 34).

Interpretation. The limited lateral extent, the association with tidal channel deposits and the basinward dip directions suggest that the clinoforms were formed by progradation of ebb-tidal deltas onto the shelf in front of tidal channels. The structures are very similar to those documented from the Lower Eocene Roda Sandstone in the southern Pyrenees, and those of the present-day tidal and ebb-delta environment of the Eastern Scheldt mesotidal system, south-west Netherlands (Yang & Nio, 1989; Crumeyrolle *et al.*, 1993). The limited extent of the sets in 2-D strike sections indicates that the lobes were 2–10 km wide. The systematic change in palaeocurrent directions of the small 2-D and 3-D dunes and ripples, which form the intrasets, shows that they migrated with an increasingly oblique angle down the surface of the ebb-tidal delta. The association with tidal channel and subtidal sand sheet deposits suggest that the intrasets formed from ebb-tidal currents. The mudstones separating the intrasets may be the result of tidal slack-water periods.

The sharp upper erosional surface of the clinoform beds, overlain by marine mudstones, was formed by shoreface erosion during an ensuing transgression.

Fossils. A few fragmented belemnites and bivalves occur. Rare trace fossils include *Diplocraterion parallelum, Planolites beverleyensis* and *Teichichnus* isp. (Dam, 1990b).

Boundaries. The upper boundary is sharp and erosional and is overlain by mudstones of the Skævdal Member (Figs 34–37). The lower boundary is more diffuse, but is placed at the base of the first thin coarsening-upward succession grading into the clinoform beds.

Distribution. The member only occurs at Harris Fjeld.

Geological age. The member is considered to be time-equivalent to the Nathorst Fjeld and Lepidopteriselv Members, suggesting an Early Toarcian age.

Fig. 35. Heterolithic clinoform bed (Facies association r) of an ebb-tidal delta of the Harris Fjeld Member. The complex is composed of two smaller and one larger coarsening-upward successions. The larger succession shows low-angle clinoform bedding with dips less than 15°. Along the clinoforms, mudstone layers alternate with intrasets of cross-bedded sandstones with mudstone drapes and mudstone clasts. TSE - Transgressive surface of erosion. Harris Fjeld. See Fig. 1 for location. From Dam & Surlyk (1995).

Fig. 36. Sandy clinoform bed (Facies association r) of an ebb-tide delta of the Harris Fjeld Member at Harris Fjeld. See Fig. 1 for location. Set is 21 m thick. TSE - Transgressive surface of erosion.

Fig. 37. Sandy clinoforms below an erosional transgressive surface (TSE) of the Harris Fjeld Member. Note the upper erosional boundary of the ebb-tidal delta (Facies association r), succeeded by mudstones. Harris Fjeld. See Fig. 1 for location.

Skævdal Member

new member

History. Strata now referred to the Skævdal Member were previously included in the Ostreaelv Member of Surlyk *et al.* (1973).

Name. The member is named after the ravine Skævdal in Neill Klinter, in the south-eastern part of Jameson Land (Fig. 1).

Type and reference localities. A well-exposed section in the cliff at Skævdal is designated the type section. Well-exposed reference sections occur at Nathorst Fjeld and Lepidopteriselv (Figs 1, 38).

Thickness. The member is 31 m thick at the type section, 4 m at Harris Fjeld, and 12 m at Nathorst Fjeld.

Lithology. The member consists of bioturbated and fossiliferous sandy mudstones and muddy very fine to fine-grained sandstones, locally containing phosphate nodules (Figs 39, 40). Primary physical structures have not been observed in the muddy sandstones. Wave ripples, hummocky cross-stratification, cross-bedding and cross-lamination are locally present in the fine to medium-grained sandstones. Ooids occur scattered in the mudstones at Horsedal.

Facies association and depositional environment. The member is entirely made up of bioturbated shoreface deposits (Facies association o).

o. Bioturbated shoreface association. This association is characteristic of the Skævdal Member. The association consists of bioturbated sandy mudstones and muddy sandstones, locally containing phosphate nodules. It forms a thoroughly bioturbated basin-wide succession, up to 31 m thick. The bioturbated deposits are characterised by the *Curvolithos* ichnocoenosis dominated by *Curvolithos multiplex*, but also include common *Thalassinoides* isp., *Ophiomorpha nodosa, Rhizo-*

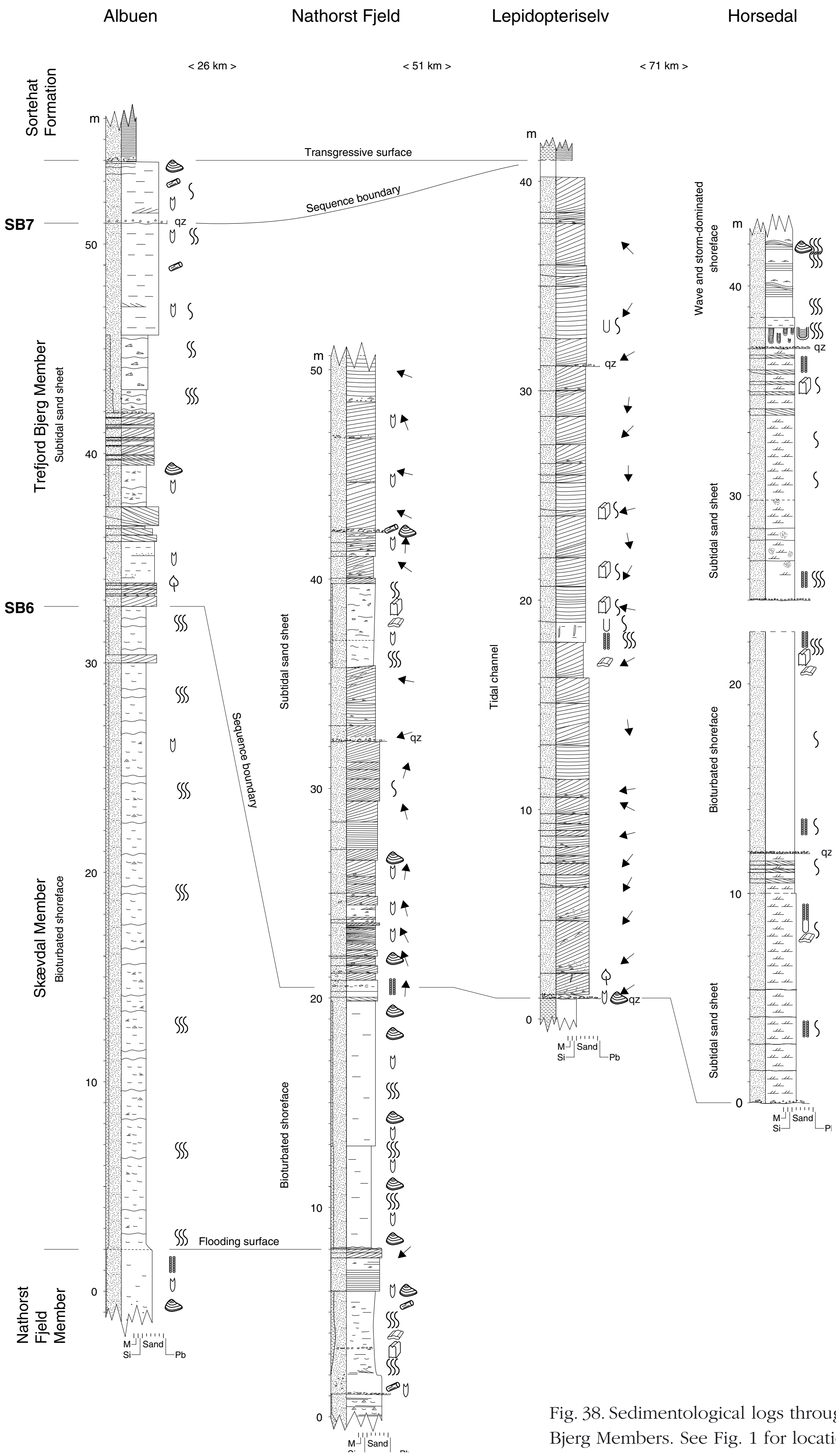


Fig. 38. Sedimentological logs through the Skævdal and Trefjord Bjerg Members. See Fig. 1 for location and Plate 1 for legend.

corallium irregulare, Gyrochorte comosa, Planolites beverleyensis, Arenicolites isp. 1 (Dam, 1990a), *Diplocraterion parallelum, Palaeophycus* isp. and rare *Cruziana* isp. and *Taenidium serpentinum* (Dam, 1990a, b). Belemnites and bivalves are common.

Along Neill Klinter, vertical alternations in mud content in the heavily bioturbated muddy sandstones of the Skævdal Member suggest that the sediments were originally deposited as heteroliths (Figs 39, 40).

Interpretation. The high degree of bioturbation and the lack of physical structures indicate a relatively slow sedimentation rate, little physical reworking and abundant food supply. The *Curvolithos* ichnocoenosis reflects a diverse fauna of infaunal and epifaunal suspension and deposit-feeding organisms, as well as carnivores. The trophically diverse fauna lived in a well-aerated environment (Dam, 1990b). Phosphatic concretions probably formed within the anoxic zone just below the sediment-seawater interface during low sedimentation rates (cf. Cook, 1976; O'Brien *et al.*, 1990).

Fossils. Fossils occur at several levels and comprise belemnites (including *'Parabrachybelus' subaduncatus*), bivalves, brachiopods and rare ammonites. Trace fossils include abundant *Curvolithos multiplex*, common *Thalassinoides* isp., *Ophiomorpha nodosa, Rhizocorallium irregulare, Gyrochorte comosa, Planolites beverleyensis, Arenicolites* isp., *Diplocraterion parallelum, Palaeophycus* isp., *Phoebichnus trochoides* and rare *Cruziana* isp. and *Taenidium serpentinum*.

Fig. 39. Bioturbated heterolithic deposits (Facies association o) of the Skævdal Member at Albuen, showing a slight coarsening-upward trend. The original heterolithic nature of the deposits can still be recognized in spite of the complete bioturbation of the sediments. See Fig. 1 for location.

Fig. 40. Detail of the bioturbated sediments (Facies association o) of the Skævdal Member at Albuen. See Fig. 1 for location. Pen 14 cm long.

Fig. 41. Erosional unconformity separating bioturbated sandy shoreface mudstones (Facies association o) of the Skævdal Member from overlying cross-bedded tidal channel sandstones (Facies association m) of the Trefjord Bjerg Member. Lepidopteriselv. See Fig. 1 for location. Persons for scale. From Dam & Surlyk (1995).

Fig. 42. Erosional unconformity separating bioturbated sandy shoreface deposits (Facies association o) of the Skævdal Member from the overlying cross-bedded sandstones (Facies association m) of the Trefjord Bjerg Member. Notice the upward thinning of cross-bedded sets. SB6 – Sequence boundary 6. Lepidopteriselv. See Fig. 1 for location.

Boundaries. The lower boundary is sharp and in places erosional and placed where the muddy sandstones and sandy mudstones of the Skævdal Member overlie the sandstones of the Nathorst Fjeld, Harris Fjeld and Lepidopteriselv Members. The upper boundary to the sandstones of the Trefjord Bjerg Member is sharp and erosional at Lepidopteriselv (Figs 38, 41, 42) and Horsedal and sharp, but non-erosional along Neill Klinter.

Distribution. The distribution of the Skævdal Member is the same as for the Neill Klinter Group.

Geological age. The presence of the belemnite *'Parabrachybelus' subaduncatus* suggests a latest Toarcian Levesquei Zone age for the Skævdal Member, whereas the ammonite *D. semicelatum* found at the base of the member (C. Bjerrum, personal communication, 1996) indicates an Early Toarcian Tenuicostatum Zone, Semicelatum Subzone age. This suggests that either the ammonite is reworked or the Skævdal Member has a very long age range (see discussion earlier). Palynomorphs suggest a Late Toarcian – Early Aalenian age (Koppelhus & Dam, in press).

Trefjord Bjerg Member

new member

History. Strata now referred to the Trefjord Bjerg Member include the uppermost part of the Ostreaelv Member of Surlyk *et al.* (1973).

Name. The member is named after Trefjord Bjerg, west of the head of Carlsberg Fjord (Fig. 1).

Type and reference localities. One of the most well-exposed and complete developments of the member occurs at Lepidopteriselv, along the southern slope of Trefjord Bjerg; this is designated the type section. Well-exposed reference sections occur along Neill Klinter at Albuen, at Harris Fjeld and Nathorst Fjeld and at Ostreaelv and Horsedal.

Thickness. The member is *c.* 40 m thick at the type section, 30 m at Ostreaelv, 21 m at Albuen, 45 m at Harris Fjeld, and at least 43 m at Horsedal.

Lithology. At Ostreaelv, along Neill Klinter, and at Nathorst Fjeld the member is dominated by fine to very coarse-grained sandstones. Many sandstones are cross-bedded and rhythmical clay drapes are common on

Fig. 43. Bored siderite clasts from the basal conglomerate of the Trefjord Bjerg Member at Lepidopteriselv. See Fig. 1 for location. Scale 1 cm on rock (encircled).

the foresets. Concretionary cement has hardened some beds. At the type section the member consists of medium to very coarse-grained, concretionary, cross-bedded sandstones, occasionally with logs, in places with interbedded bioturbated sandstones. From Lepidopteriselv towards west to Liaselv and towards south the cross-bedded sandstones pass laterally into medium-grained bioturbated sandstones. At Horsedal the member is composed of cross-bedded, cross-laminated, parallel-laminated and hummocky cross-stratified fine to medium-grained sandstones alternating with bioturbated sandstones. At this locality thin conglomerates, composed of discoidal quartzite pebbles, occur at several levels.

Facies associations and depositional environments. The member is made up of three facies associations (m, n and o).

m. Tidal channel association. This association is characteristic of the member at the type locality, where it is cliff-forming. It consists dominantly of planar and elongate trough cross-bedded medium to very coarse-grained glauconitic sandstones (Figs 38, 41, 42), and less commonly of parallel and cross-laminated sandstones. Thin mudstone drapes may occur in couplets on the foresets (cf. Visser, 1980), and flatten out along

Fig. 44. Interbedded bioturbated (I) and parallel-laminated and hummocky cross-stratified (II) very fine to fine-grained sandstones of the wave and storm-dominated shoreface association (n). Trefjord Bjerg Member, Horsedal. See Fig. 1 for location. Hammer 32 cm long.

the toesets, where they extend as horizontal layers for several metres. Mudstone drapes may extend to the top of the foresets or pinch out on the mid-foreset slope due to truncation by reactivation surfaces. The coupled mudstone drapes enclose a thin sand layer displaying cross-lamination with a foreset orientation opposite to that of the cross-bedding. Groups of foresets may display a repetitive lateral thickening and thin- ning, similar to the bundle sequences of Visser (1980). Set thickness varies from 0.2 to 3.5 m with 0.5 to 2 m being the most common. The troughs commonly exceed 15 m in width. Foresets are tangential and dip angles range from 14° to 31°. Logs, pebbles, and transported assemblages of belemnites, bivalves and occasional crinoids occur in the basal part of the sets. The cross-bedded sets form a coset, 40 m thick, with a general thinning upward in set thickness (Figs 38, 42). The lower surface of the coset is erosional and overlain by a thin lag conglomerate of belemnites, bivalves, well-rounded quartzitic pebbles less than 2 cm in diameter, and bored siderite clasts (Fig. 43). The foresets dip unimodally towards SW. Sets are in places separated by bioturbated sandstones. The bioturbated sandstones include *Arenicolites* isp. 2, *Curvolithos multiplex, Diplocraterion habichi, Gyrochorte comosa, Ophiomorpha nodosa* and *Rhizocorallium* isp. (Dam, 1990a). The top of the sandstone unit at several localities at Lepi-dopteriselv is heavily bioturbated by *Diplocraterion habichi,* and loose blocks also suggest *Phycodes bromleyi*.

Interpretation. The cross-bedded sandstones were deposited by extensive fields of migrating small and medium-scale 2-D and 3-D dunes. The presence of mudstone couplets and foreset bundles indicates that deposition took place in a subtidal environment with ordinate and subordinate currents (Visser, 1980). The lower erosional boundary of the cross-bedded cosets, the general offshore directed currents and the upward thinning of set thickness suggest deposition in the ebb-dominated subtidal part of a tidal channel. The trace fossil assemblage represents a low diversity assemblage of organisms that adapted themselves to well-aerated high-energy environments of great physical instability. The lack of burrow linings, great morphological vari- ability and scattered distribution suggest that *Arenico-lites* isp. 2 must have acted as shelters for only a short period of time and not as permanent domiciles, indicating a high sediment influx (Dam, 1990a, b). The complex clay-ball-lined walls of *Ophiomorpha nodosa* indicate moderate to high sediment influx and a low rate of reworking (Heinberg & Birkelund, 1984).

n. Wave and storm-dominated shoreface association. This association constitutes the Trefjord Bjerg Member in the northern part of the basin. It consists of single or amalgamated beds of parallel laminated, hummocky and swaley cross-stratified, very fine to fine-grained sandstones. The beds have flat, sharp and erosional bases, occasionally succeeded by thin lag conglomerates consisting of well-sorted, well-rounded, oval quartzitic pebbles and cobbles. Parallel lamination with parting lineation is commonly the main, or only, sedimentary structure (Fig. 44). Abundant transported bivalves are common in the laminae, and include *Astarte* sp., *Corbicellopsis unioides, Modiolus (Strimo-diolus) elongatus and Pleuromya uralensis.* Wave ripple cross-laminated sandstones and symmetrical ripples usually cap the beds. A maximum depositional depth for the wave ripple laminated beds of approximately 13 m is estimated on the basis of wave ripple features, using the method of Diem (1985). Bioturbated very fine to fine-grained sandstones, 0.1–1 m thick, occur interbedded with the parallel-laminated, hummocky and swaley cross-stratified sandstones. The beds are thoroughly bioturbated and characterised by the *Rhizocorallium* and *Phoebichnus* ichnocoenoses of Dam (1990b). The *Rhizocorallium* ichnocoenosis consists primarily of *Rhizocorallium irregulare, Gyrochorte comosa, Parahaentzschelinia surlyki, Curvolithos multiplex, Nereites* isp., and rare *Scolicia* isp., *Gyrophyllites kwassicensis* and trackways. The *Phoebichnus* ichnocoenosis is monospecific, only including the complex burrow *Phoebichnus trochoides*, occurring in very large numbers at certain levels.

Interpretation. The sharp bases of individual sandstone beds and the dominance of parallel lamintion suggest episodic deposition from waning flows characterised by combined flow-processes or intense bed shear due to storm-wave activity. Hummocky cross-stratification is formed by aggradation or translation in a combined or oscillatory flow regime (Dott & Bourgeois, 1982; Swift *et al.*, 1983; Allen, 1985; Surlyk & Noe-Nygaard, 1986). Amalgamation of beds is caused by scouring and erosion above storm-wave base with the removal of the fine-grained, bioturbated caps (Dott & Bourgeois, 1982; Leithold & Bourgeois, 1984). The interbedding with heavily bioturbated, wave ripple laminated sandstones suggest deposition at or just below fair-weather wave-base and above storm wave-base. The transported bivalves include both shallow and deep burrowing forms (cf. Fürsich, 1982, 1984). The latter indicating that deep erosion frequently occurred on the shoreface during storms.

The *Rhizocorallium* ichnocoenosis represents the activity of both deposit-feeding organisms and carnivores (Dam, 1990a, b). The ichnocoenosis is present in horizons that represent well-aerated periods of relative low-energy conditions. The *Phoebichnus* ichnocoenosis reflects a monospecific fauna of exclusively deposit-feeding organisms and is indicative of very quiet conditions with deposition of organic-rich material (Heinberg & Birkelund, 1984). This type of stationary fodinichnial ichnocoenosis probably exemplifies an oxygen-limited environment that was exploited thoroughly by a population of opportunistic organisms (cf. Ekdale & Mason, 1988).

o. Bioturbated shoreface association. This association consists of bioturbated fine to medium-grained sandstones, locally containing phosphate nodules. It forms thoroughly bioturbated successions, up to 55 m thick, laterally intercalated with tidal channel and wave and storm-dominated shoreface deposits (Facies associations m and n). Primary physical structures are rare and include wave ripples, hummocky cross-stratification, cross-bedding and cross-lamination. The bioturbated deposits are characterised by the *Curvolithos* ichnocoenosis dominated by *Curvolithos multiplex*, but also include common *Thalassinoides* isp., *Ophiomorpha nodosa, Rhizocorallium irregulare, Gyrochorte comosa, Planolites beverleyensis, Arenicolites* isp. 1, *Diplocraterion parallelum, Palaeophycus* isp., rare *Cruziana* isp. and *Taenidium serpentinum* (Dam, 1990a, b). Belemnites and bivalves are common.

Interpretation. The high degree of bioturbation and the general scarcity of preserved physical structures indicate a relatively low sedimentation rate, little physical reworking and abundant food supply. The *Curvolithos* ichnocoenosis reflects a diverse fauna of infaunal and epifaunal suspension and deposit-feeding organisms, as well as carnivores. The trophically diverse fauna lived in a well-aerated environment (Dam, 1990b).

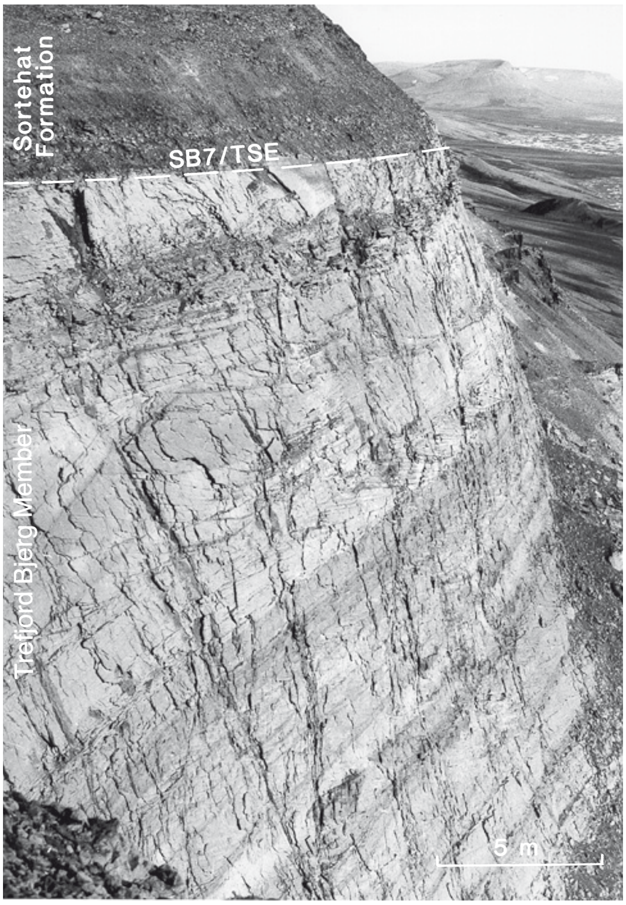


Fig. 45. Cross-bedded sandstones of the Trefjord Bjerg Member overlain by black mudstones of the Sortehat Formation. The boundary is interpreted as a coalesced sequence boundary and transgressive surface. SB7 - Sequence boundary 7, TSE - Transgressive surface of erosion. North of Astartekløft. See Fig. 1 for location. From Dam & Surlyk (1995).

Phosphatic concretions probably formed within the anoxic zone just below the sediment-seawater interface during low sedimentation rates (cf. Cook, 1976; O'Brien *et al.*, 1990).

Fossils. Fossils are common at several levels and include bivalves, belemnites and ammonites. Trace fossils include abundant *Curvolithos multiplex, Ophiomorpha nodosa, Phoebichnus trochoides, Taenidum serpentinum, Thalassinoides* isp., common *Arenicolites* isp., *Diplocraterion habichi, Diplocraterion parallelum, Rhizocorallium irregulare, Thalassinoides* isp., *Gyrochorte comosa, Nereites* isp. *Parahaentzschelinia surlyki, Planolites beverleyensis* and rare *Cruziana* isp., *Gyrophyllites kwassicensis, Scolicia* isp., and trackways.

Boundaries. At Ostreaelv, Trefjord Bjerg and Horsedal, the coarse-grained sandstones of the Trefjord Bjerg Member rest with a sharp, erosional boundary on the muddy sandstones of the Skævdal Member. The boundary is overlain by a lag of bored siderite clasts, extraformational pebbles, logs and belemnites (Figs 41–43). Along Hurry Inlet there is a sharp non-erosional contact to the underlying Skævdal Member. The upper boundary is placed at the sharp change from the sandstones of the Trefjord Bjerg Member to the overlying dark silty mudstones of the Sortehat Formation (Fig. 45).

Distribution. The distribution of the Trefjord Bjerg Member is the same as for the Neill Klinter Group.

Geological age. None of the fossils found in the Trefjord Bjerg Member are age diagnostic. The presence of the belemnite *'Parabrachybelus' subaduncatus* in the underlying Skævdal Member, suggests an age no older than the uppermost Toarcian Levesquei Zone. Palynomorphs suggest a Late Toarcian – earliest Aalenian age (Koppelhus & Dam, in press).

Sortehat Formation

redefined

History. The strata composing the Sortehat Formation were originally defined as the basal member of the Middle Jurassic Vardekløft Formation (now Vardekløft Group) by Surlyk *et al.* (1973). They were recently excluded from this formation and first established informally as a member of the Neill Klinter Formation, later as a separate formation (Surlyk, 1990a, b, 1991). It is here included in the Neill Klinter Group. A detailed description is presented in Koppelhus & Hansen (in press).

Name. From the mountain Sortehat by Ugleelv at the head of Hurry Inlet (Fig. 1).

Type and reference localities. One of the most complete and well-exposed sections occurs at Sortehat which is designated the type section. Well-exposed reference sections occur at Albuen, Goniomyakløft, Trefjord Bjerg, Liaselv, Pelion, Coloradodal and Pingel Dal (Fig. 1).

Thickness. The thickness varies between 60 and 120 m (Surlyk *et al.*, 1973). At the type locality it is *c.* 100 m thick (Krabbe *et al.*, 1994).

Lithology. The member is very uniform throughout the exposed parts of the basin. The lower part consists of dark-grey to black mudstone with concretionary layers and nodules of claret-coloured ironstone. In the upper part the mudstones become more silty, the ironstone decreases or disappears and lenses or layers of fine sandstone, partly concretionary, appear in the succession. The upper part may contain layers of calcareous concretions. Fossils include bivalves, mainly oyster fragments, and belemnites which commonly occur in the top of the formation. Plant fragments are common. Part of the mudstones and fine sandstones are burrowed by *Curvolithos multiplex* and *Planolites beverleyensis* (Surlyk *et al.*, 1973; Krabbe *et al.*, 1994).

Facies association and depositional environment. One facies association is recognised in the Sortehat Formation (s).

s. Restricted embayment association. This association consists of silty mudstone with very fine and fine-grained micaceous sandstone streaks. The sandstone streaks show pinch and swell structures, incipient lenses and parallel lamination grading into wave ripple cross-lamination. The streaked mudstones locally contain highly disintegrated plant debris and wood fragments, early diagenetic phosphate concretions and calcare- ous concretionary layers. Fossils include bivalves, mainly oyster fragments, and belemnites which commonly occur in the top of the formation. At Albuen a large number of inarticulate brachiopods occur in the basal part of the formation. The mudstones form one or two coarsening-upward successions, and are commonly burrowed by *Curvolithos multiplex* and *Planolites beverleyensis* (Surlyk *et al.*, 1973; Krabbe *et al.*, 1994).

Interpretation. The mudstones were deposited in an offshore environment, probably in a relatively deep embayment with restricted wave energy. The very fine and fine-grained sandstones were deposited as tempestites during periodic storms in water depths below fair-weather wave base but above storm-wave base. The coarsening-upward successions are shallowing-upward cycles with offshore deposits overlain by lower shoreface deposits. The sands were probably derived from coastal erosion and transported by downwelling flows during storms (cf. Snedden *et al.*, 1988). Both macrofossils, organic geochemistry (Krabbe *et al.*, 1994) and palynomorphs (Koppelhus & Hansen, in press) suggest an increase of salinity in the depositional environment from the base to the top of the formation.

Fossils. Fossils include bivalves, mainly oyster fragments, and belemnites which commonly occur in the top of the formation. The sediments are commonly burrowed by *Curvolithos multiplex* and *Planolites beverleyensis.*

Boundaries. The boundary between the Sortehat and Ostreaelv Formations is one of the most conspicuous lithological boundaries in the Mesozoic succession of East Greenland. Throughout the exposed part of the basin the contact between the sandstones of the Neill Klinter Group and the dark mudstones of the Sortehat Formation is flat and very sharp and in places pebble strewn. The Sortehat Formation is overlain by the sandy Vardekløft Group with a sharp, unconformable contact (Surlyk *et al.*, 1973; Engkilde & Surlyk, in press).

Distribution. Same as the group.

Geological age. No age diagnostic macrofossils have been found. Palynomorphs suggest an Aalenian – Early Bajocian age of the formation (Underhill & Partington, 1994; Koppelhus & Hansen, in press).