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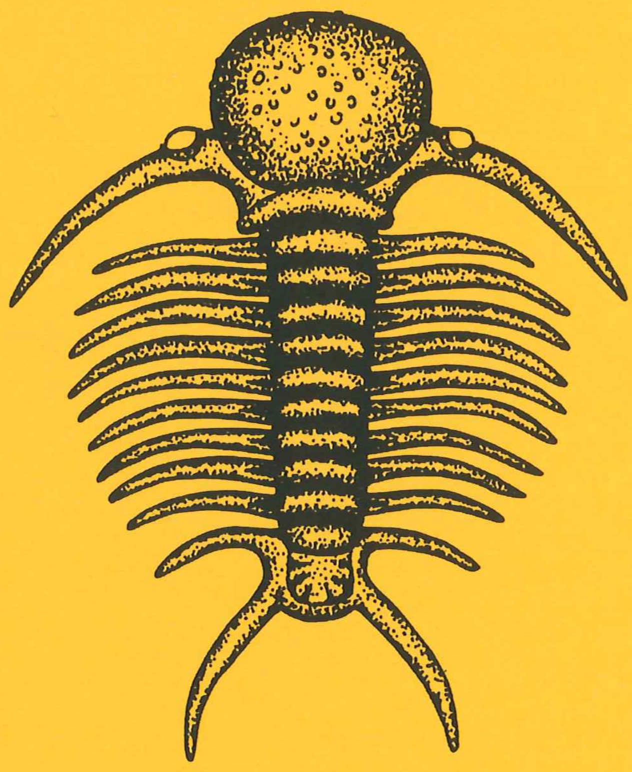
Historisk geologi och paleontologi



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Coden:SE-LUNBDS/NBGO-96/5068+23S

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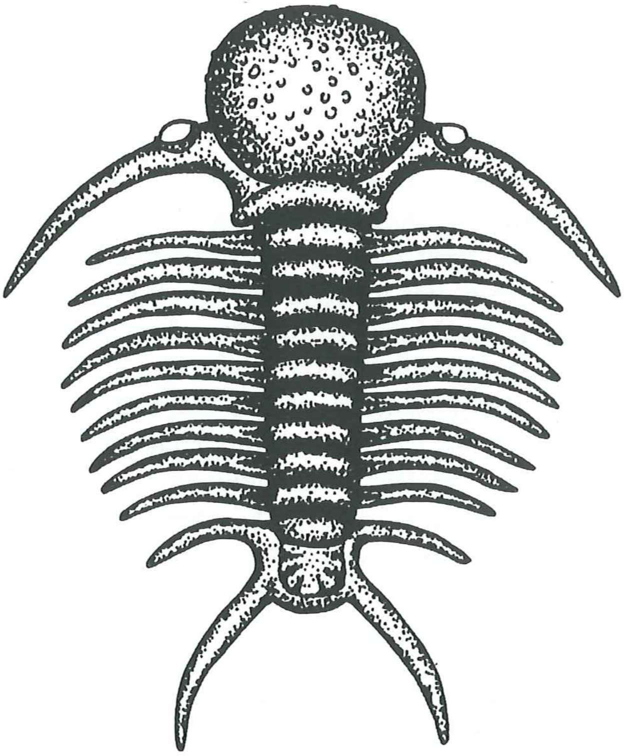

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INGELA OLSSON

Olsson, I., 1996 03 05: Sedimentology of the Bajocian Fuglunda Member at Eriksdal, Scania, southern Sweden. *Examensarbete i geologi vid Lunds Universitet*. 20 poäng. Nr. 68, 1-23.

The Bajocian Fuglunda Member of Eriksdal consists mostly of sand, silt and coal arranged in cycles (2-4 m). Each cycle generally starts with organic-rich heteroliths at the base and further up ripple-drift cross laminated and horizontally laminated fine sand follow. The coal seams at the top of the cycles are of minor thickness. Signs of soil formation occur as coalified rootlets reaching down from the seams, and as soil horizons with upper erosive boundaries. Evidence of lacustrine as well as brackish and marine conditions are represented in the strata. The coal seams contain a flora of fresh water plants, whereas pyrite nodules, *Diplocraterion* and calcareous foraminifera are characteristics of brackish or marine conditions. The different sediments were divided into two populations interpreted as originating from mainly river generated and beach foreshore processes. The cyclic arrangement of the present sediments and their characteristics point at a lower delta plain environment, where sediments were deposited from the distributaries into the interdistributary bays. Fluctuations in sea-level, possibly due to variations in the compaction of underlying sediments, periodically exposed the bays to basinal processes.☐ *Bajocian, Fuglunda Member, coal, cyclicity, grain size analysis, river processes, beach foreshore processes, interdistributary bays, lower deltaic plain.*

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During the Jurassic Period major tectonic changes of the crust took place. The Supercontinent Pangaea broke up into several new continents. For example the formerly joined South America, Africa and Laurasia were split up as the Atlantic Ocean began to take form during the early Jurassic (Ziegler 1990). Later during the period also Gondwanaland split into two new continents when South America, Africa, India and Australia drifted apart from Antarctica (Ziegler 1990). Further to the north the tectonic movements were not as powerful as those responsible for the break-up of continents in the southern hemisphere. Still there is evidence of their existence in the form of abundant faults and traces of volcanic activity in the North Sea Region (Rolle *et al.* 1979).

Major changes in the palaeogeography and in the patterns of sedimentation were a result of tectonic activities, and in the province of Scania, southern Sweden, this is characterized by a complex block-faulted SE-NE striking zone called the Tornquist Zone (Norling & Bergström 1987). In this zone all the rocks from the restricted upper Triassic and Jurassic of Sweden are found (Norling 1972) (Fig. 1).

The climate in the Fennoscandian Border Zone (Fig. 1) changed at the transition between the Triassic and Jurassic Periods from dry to more humid as Baltica continued its journey to the north (Rolle *et al.* 1979). At the time of the Jurassic Period the Baltic Shield had reached a latitude corresponding to northern Sahara and southern China today, i.e. at about 25-30° N (Ziegler 1990).

The early middle Jurassic sedimentary record of Scania is dominated by rocks formed in lacustrine and alluvial environments although traces of marine and brackish interruptions are also evident (Rolle *et al.* 1979). Since the Ringkøbing-Fyn High (Fig. 2), to the west of the narrow depositional area of Scania, acted as a vast denudation area, terrigenous material was abundant (Norling *et al.* 1993).

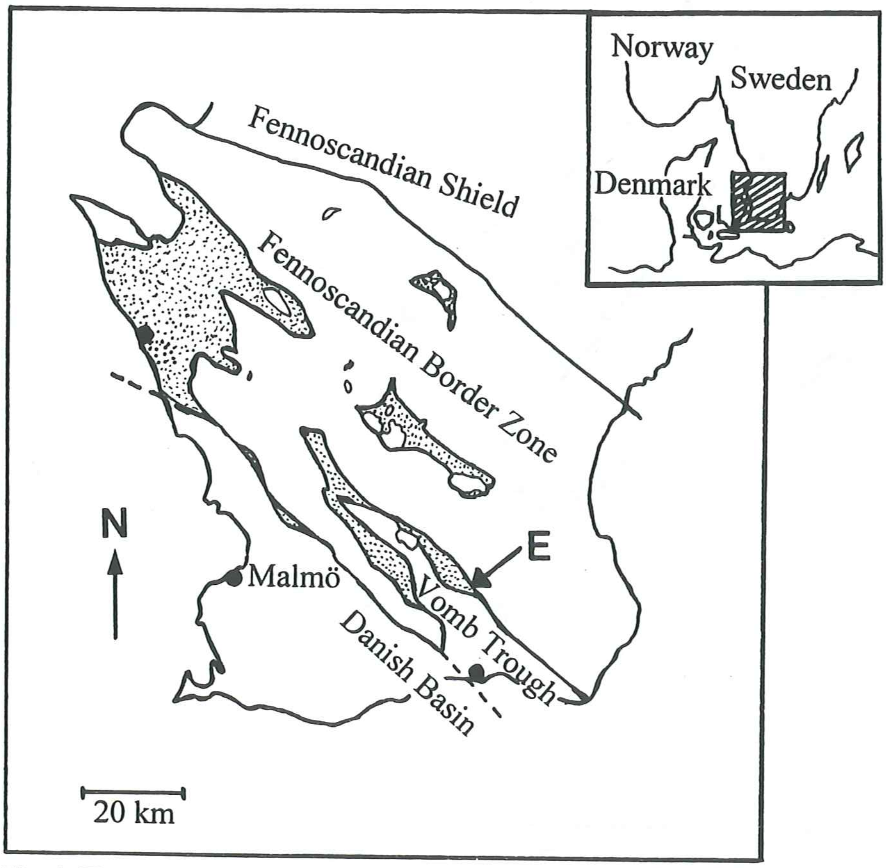

Fig. 1. The distribution of the Upper Triassic (Rhaetian) and Jurassic rocks in Scania. E points at Eriksdal. (After Norling 1972).

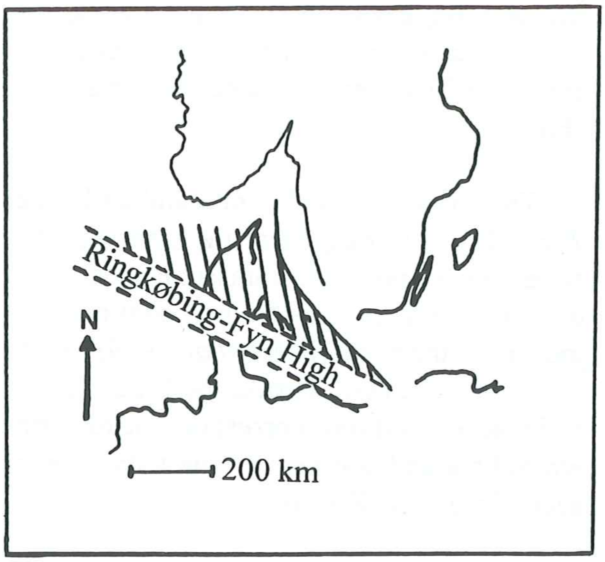

Fig. 2. The Ringkøbing-Fyn High denudation area. (After Rolle *et al.* 1979).

The sediments formed in this Jurassic landscape differ between the northwestern and western south-central part of Scania (Sivhed 1984). According to Sivhed (1984) the northwestern region is dominated by clayish and silty deposits of the Vilhelmsfält Formation, whereas the Fuglunda Member and Glass Sand Member of the south are characterized by argillaceous and coal-bearing respectively arenaceous and kaolinitic deposits.

The Vomb Trough and the Eriksdal Area

The Vomb Trough (Fig. 1) is an assymetric graben with a complex tectonic history in the southcentral part of Scania. Faults trending NW-SE, NE-SW and E-W is the result of Cretaceous inversion movements which also caused subduction of the trough (Norling & Bergström 1987).

Eriksdal, where today 100-200 m thick poorly consolidated Jurassic strata are exposed, is situated between Sjöbo and Tomelilla

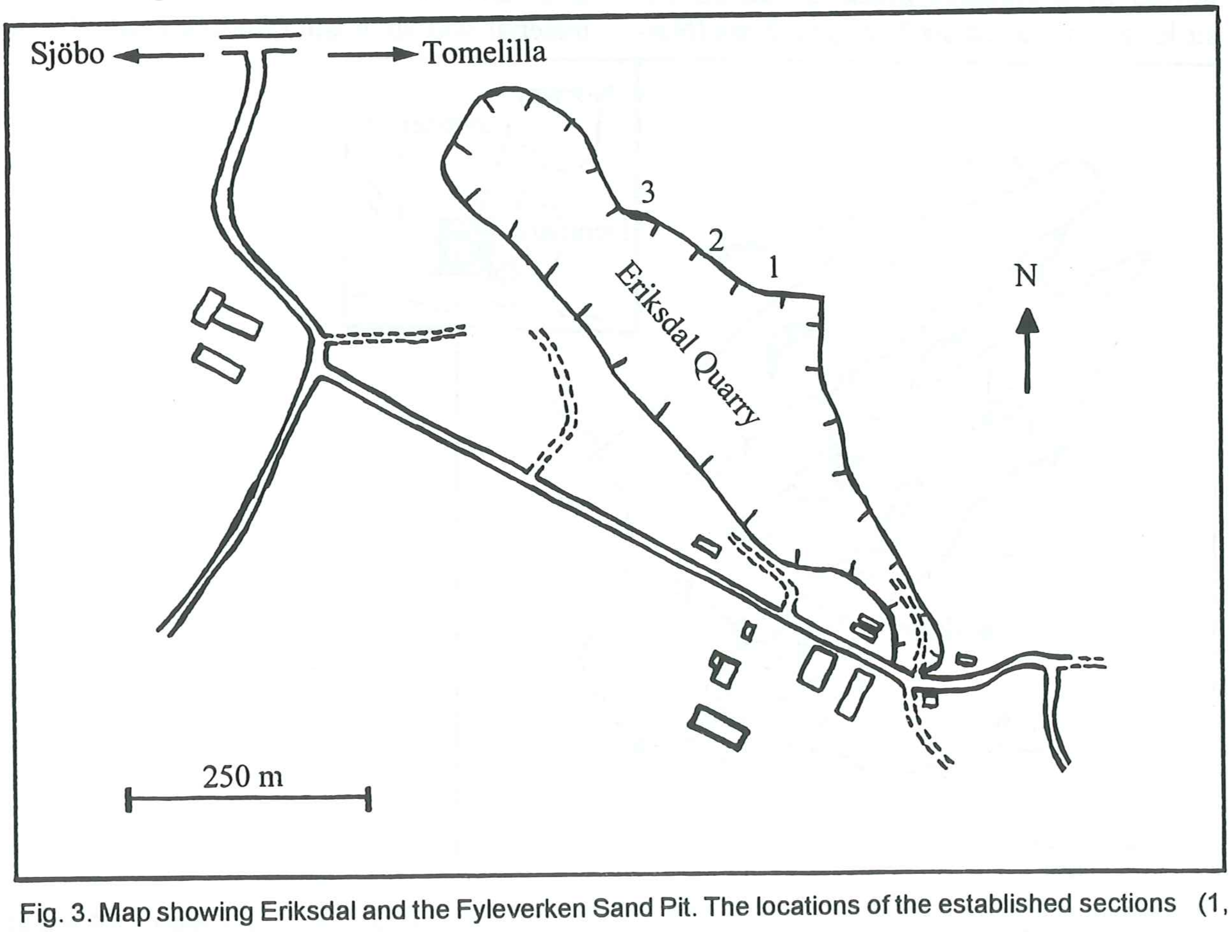

Fig. 3. Map showing Eriksdal and the Fyleverken Sand Pit. The locations of the established sections (1, 2, 3) are shown. (After Norling *et al.* 1993).

Chronostratigraphy			Formation	Member
JURASSIC	upper	Tithonian	Annero Formation	Vitabäck Clays
		Kimmeridgian		Nytorp Sand
		Oxfordian		Fyledalen Clay
	middle	Callovian	▨	▨
		Bathonian	Mariedal Formation	Glass Sand
		Bajocian		Fuglunda Mb.
		Aalenian	?	
	lower	Toarcian	Röddinge Formation	*No defined members*
		Pliensbachian		
		Sinemurian		
		Hettangian	▨	▨

Fig. 4. Stratigraphy of the Jurassic at Eriksdal (After Norling *et al.* 1993).

along Riksväg 12 in the northeastern part of the Vomb Trough (Fig. 1). The tectonic movements in the area have caused the strata to be slightly overthrusted with an approximate strike of N40°W and dip 80°NE. In the Fyleverken Sand Pit (Fig. 3) the Middle Jurassic (Bathonian) Glass Sand Member is beeing quarried. Except for the Glass Sand Member three other lithological units are exposed at Eriksdal; the Bajocian Fuglunda Member (former Eriksdal Beds), the Upper Jurassic Fyledal Clay and the Upper Jurassic-Cretaceous transitional Vitabäck Clays (Norling *et al.* 1993) (Fig. 4).

A regression caused by fault movements in the marginal blocks of the Fennoscandian Border Zone took place during Bajocian-Bathonian time (Rolle *et al.* 1979). The sediments deposited are continental with minor marine intercalations, i.e. sand, clay and coal arranged in cycles.

The Fuglunda Member (Mariedal Formation) is named after a farm situated north of the Fyleverken Sand Pit. Tralau (1968) used the name Eriksdal beds for these strata in his palynological studies. Since this name already had been used for the Santonian Eriksdal Marl (Erdmann 1873) Sivhed (1984) suggested the name to be changed to the Fuglunda Member in his litho- and biostratigraphical investigation of the Upper and Middle Jurassic in Scania.

Other papers concerning the strata at Eriksdal are: Norling (1972) dealing with the stratigraphy and foraminifera in western Scania and Norling & Bergström's (1987) study of the tectonic evolution in Scania. Descriptions of the sedimentology of the strata have been performed by Rolle *et al.* (1979), Sivhed (1984) and Norling *et al.* (1993).

The intention of this paper is to present a detailed sedimentological investigation, mainly based on grain size analysis, and as a result of this to interpret the depositional environment prevailing at Eriksdal during the deposition of the Fuglunda Member. The study includes grain size analysis, field work with logging (3 sections of different length have been established ,cf. Fig. 3), XRD-analysis and petrographic analysis.

Methods

In the field, three sections (Figs. 8, 9,10) were established and samples were collected at different intervals throughout the sections (cf. Figs. 8, 9,10). In the laboratory the samples were dried at about 50°C overnight. An amount (175 g) of each sample was stirred with warm water and the dispersant sodium hexametaphosphate. The mixture was then washed through a sieve nest (2.000 mm, 1.000 mm, 0.500 mm, 0.250 mm, 0.125 mm and 0.063 mm). The weight of the fraction in each sieve was determined after drying (same procedure as described above). The grain size distribution and some grain size parameters (median, mean, sorting and skewness) were calculated using M-Korn (a grain size program compiled by Per-Ivar Steinsund & Björn Holmquist at the Departement of Geology, Lund University, Sweden). The calculated parameters were plotted in three different scattergrams according to earlier works by Inman & Chamberlain (1955), Stewart (1958) and Friedman (1961) to enable distinction between different depositional environments. The different scattergrams show sorting plotted against median, skewness plotted against median and skewness plotted against sorting. By comparing the established scattergrams with the studies performed by Inman & Chamberlain (1955), Stewart (1958) and Friedman (1961) it was possible to decide the depositional origin of the samples. In Figs. 5a, 5b and 5c models of the three different scattergram types are shown.

The grain size fractions of all the samples were optically examined under a light microscope for petrographic analysis.

XRD-analysis (cf. Hardy and Tucker 1988) was carried out to get a fingerprint of the clay minerals of the section. Oriented clay fraction samples were run untreated, heated to 550°C, and treated with ethylene glycol.

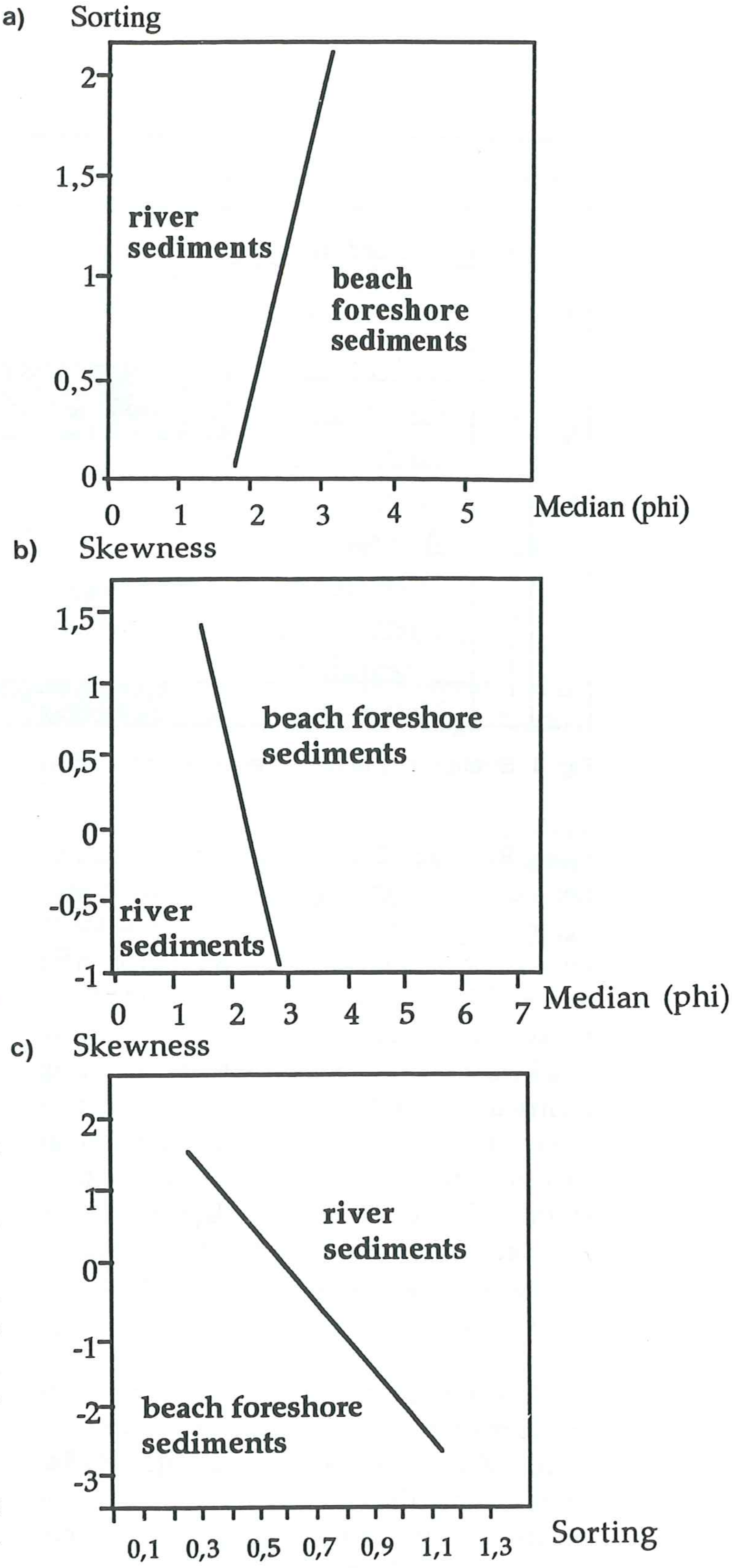

Fig. 5. Principal model of (a) scattergram with sorting plotted against median (After Stewart 1958), (b) scattergram with skewness plotted against median (After Stewart 1958) and (c) scattergram with skewness plotted against sorting (After Friedman 1961).

Results

General description of the sediments

The sediments of the Fuglunda Member are composed of poorly consolidated sand, silt, clay and coal seams arranged in a cyclic way. In the upper part of the member the sediments are more fine-grained and the cycles are vertically less extensive than in the lower part. The cycles (2-4 m) follow a general succession (Fig. 6) with heteroliths consisting of organic matter and clastic grains (silt and sand), showing flaser, wavy and lenticular bedding or as in some parts of the section ripple-drift cross lamination, at the bottom of each cycle. Sand showing ripple-drift cross lamination or horizontal lamination with *Diplocraterion* follows above. The bedding structures and the burrows are accentuated by organic matter (plant debris) draping the bedding surfaces and the walls of the burrows. Immediately under the topmost coal seam of each cycle horizontally laminated silt and sand with coal-filled rootlets occur. The lamination diminishes at the top close to the coal seam where the rootlets are most frequent. The capping coal seams are extensive laterally for about 100 m but of minor thickness (generally about 0.5 m).

Description of the sections

Section 1 is showing the oldest exposed part of the Fuglunda Member investigated in this paper. Section 2 and 3 are in part covering the corresponding strata, but differ in thickness. In section 2 the uppermost 9 m of the Fuglunda Member are described, wheras in section 3 only the uppermost 5 m are described. The positions of the sections (Figs. 8, 9, 10) in the sand pit are shown in Fig. 3.

Section 1

At the base a 2.5 m thick unit of medium- to coarse- grained horizontally laminated sand occurs, with well rounded sandstone pebbles concentrated at scattered levels. A minor coal seam is followed by finer sediments further up. Coal seams of varying thickness are present at 9 different levels of the section. The sediment making up the bulk of the section between the seams comprises very fine to fine sand with evidence of biogenic activity in the form of *Diplocraterion* burrows at certain levels. The different types of heterolithic bedding (wavy, flaser and lenticular), horizontal lamination and ripple-drift cross lamination

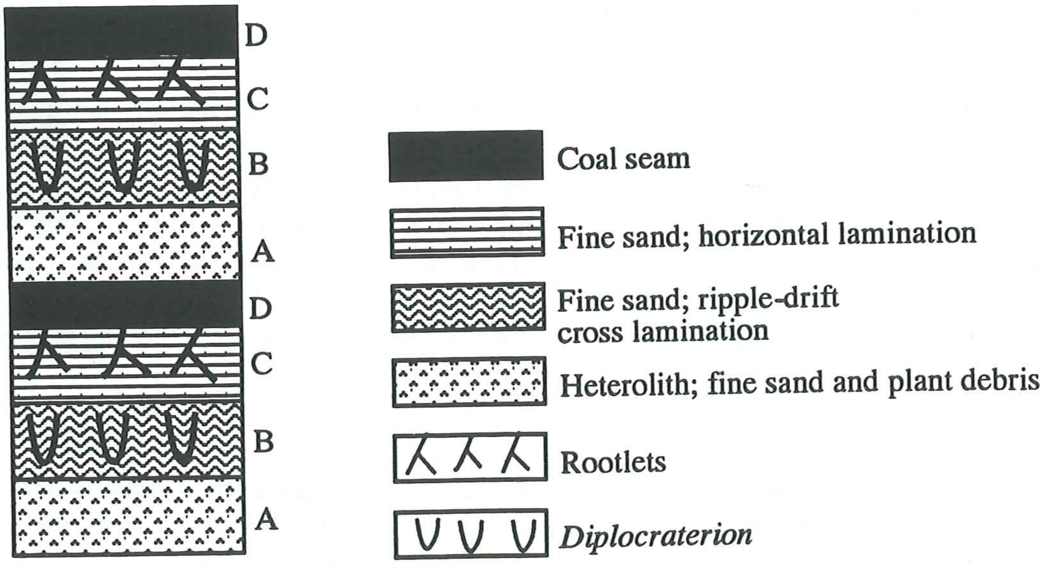

Fig. 6. A model showing two adjacent sedimentary cycles (A,B,C,D - A,B,C,D)

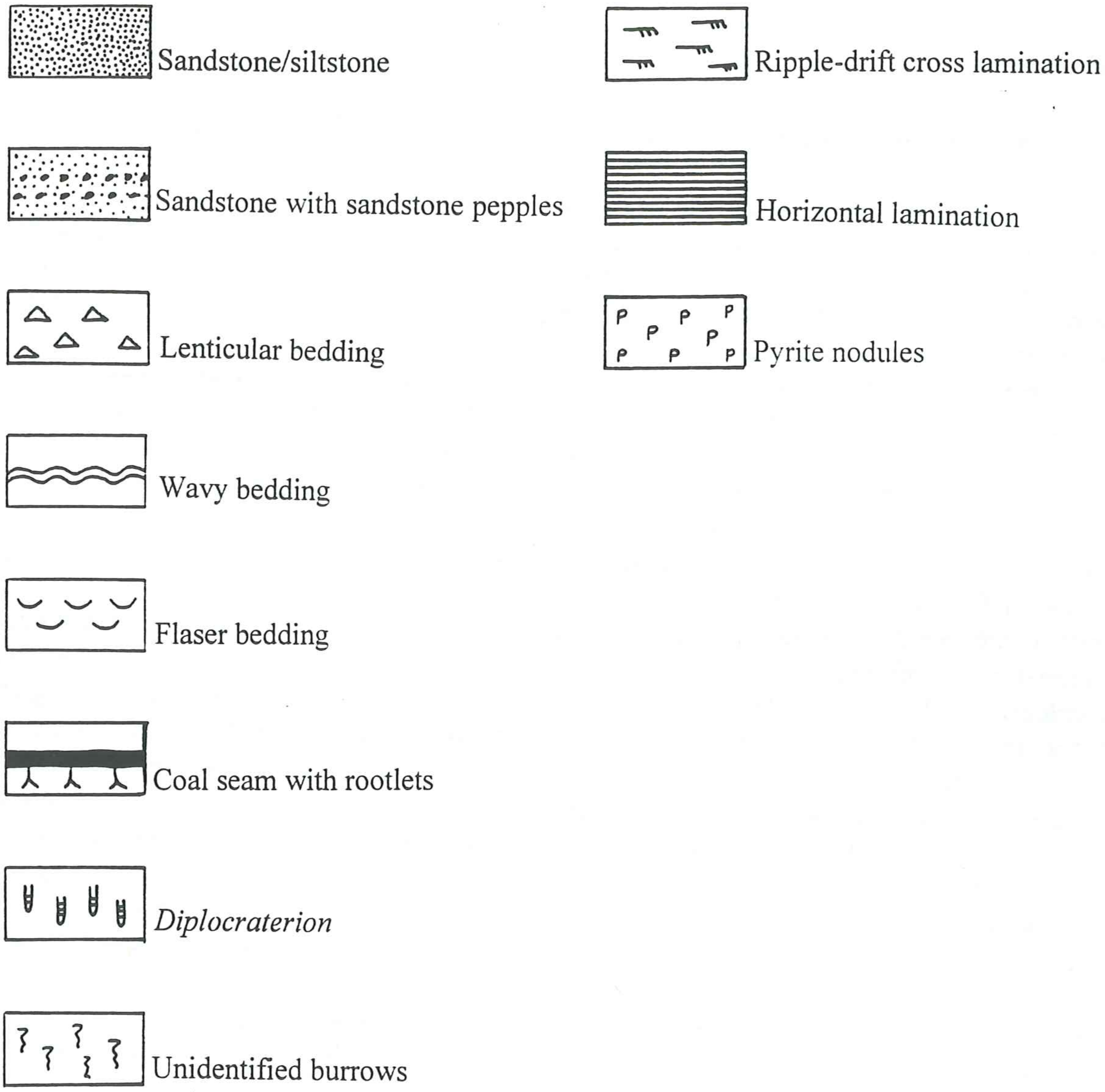

Fig. 7. Legend to the sections in Figs. 8a, 8b,9, and 10.

are represented in the section. Rootlets are reaching down from the coal seams into the horizontally laminated dark brown sand underlying the coal. This dark brown colouring is found at the top in the majority of the cycles of this section. Pyrite nodules were found at three levels in the upper part of the section.

Section 2

At the bottom of the section the sediment comprises a heterolith consisting of silt, fine sand and organic debris arranged as wavy, flaser and lenticular bedding. Higher up the amount of organic matter decreases and the sediment present is a horizontally laminated very fine to fine sand. The horizontal lamination disappears upwards and vague ripple-drift cross lamination is the dominating sedimentary structure. Through the sand, fine (a few millimetres wide) vertical cracks, approximately 1 m deep, cut the bedding planes.

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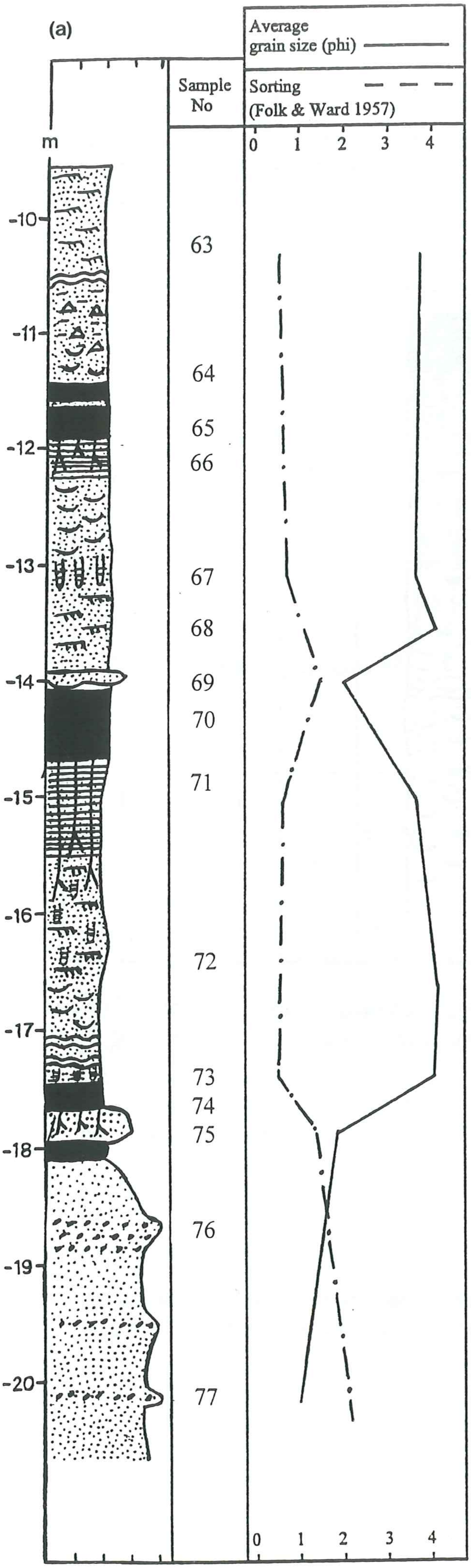
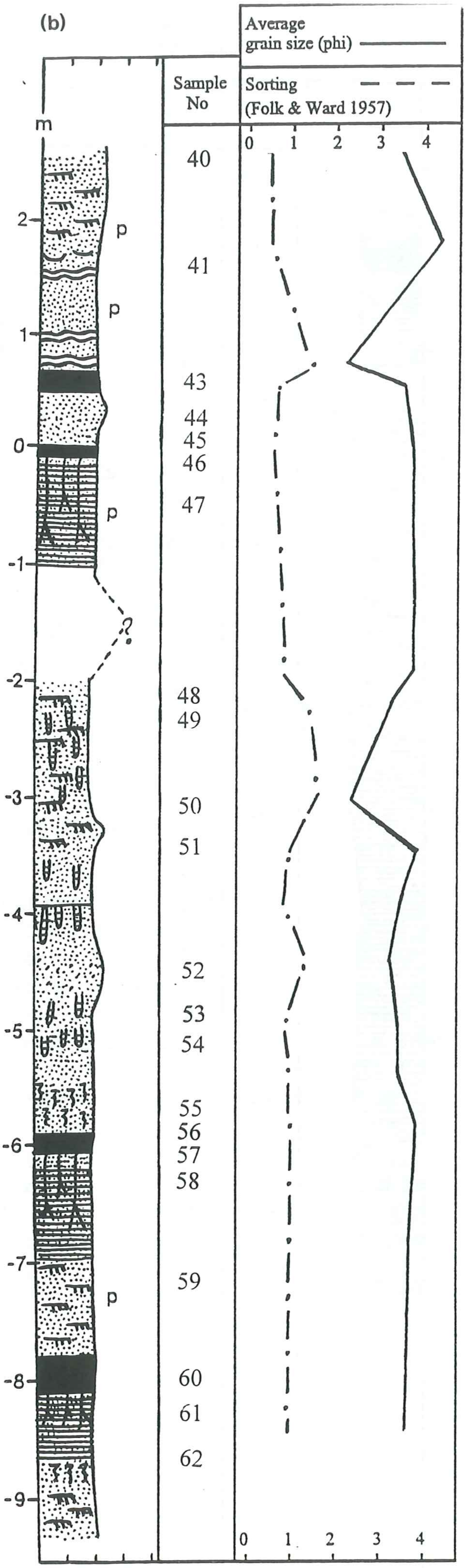
Fig. 8. Lithology, sample levels, average grain size and sorting of the lower part (a) and upper part (b) of section 1. See legend in Fig. 7.


(a)
Average grain size (phi)
Sample No
Sorting
(Folk & Ward 1957)
0
1
2
3
4
m
-10
-11
-12
-13
-14
-15
-16
-17
-18
-19
-20
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77

a


(b)
Average grain size (phi)
Sample No
Sorting
(Folk & Ward 1957)
0
1
2
3
4
m
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
p
p
p
?
p
40
41
43
44
45
46
47
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51
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53
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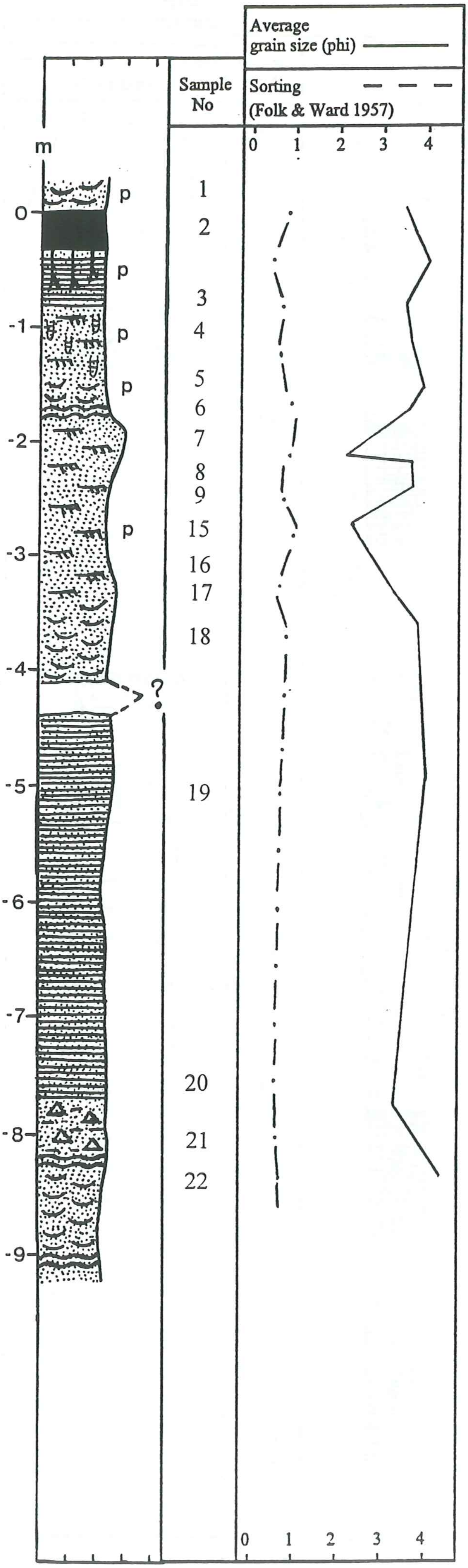
57
58
59
60
61
62

b



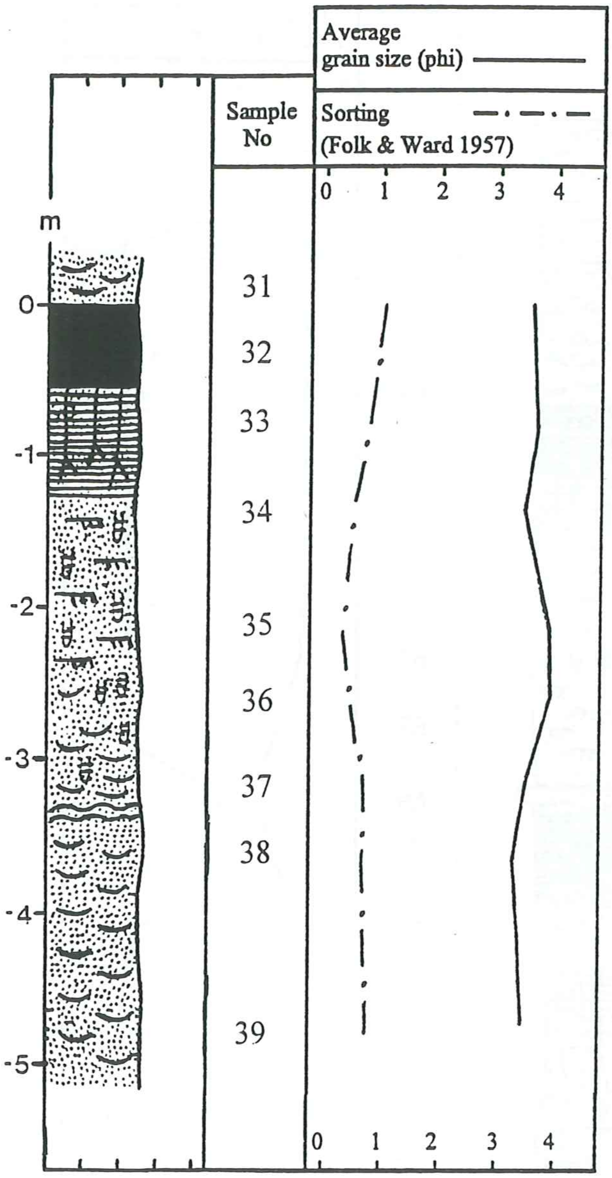


Fig.10. Lithology, sample levels, avarage grain size and sorting of section 3. See legend in Fig. 7.

Fig. 9. Lithology, sample levels, average grain size and sorting of section 2. See legend in Fig. 7.

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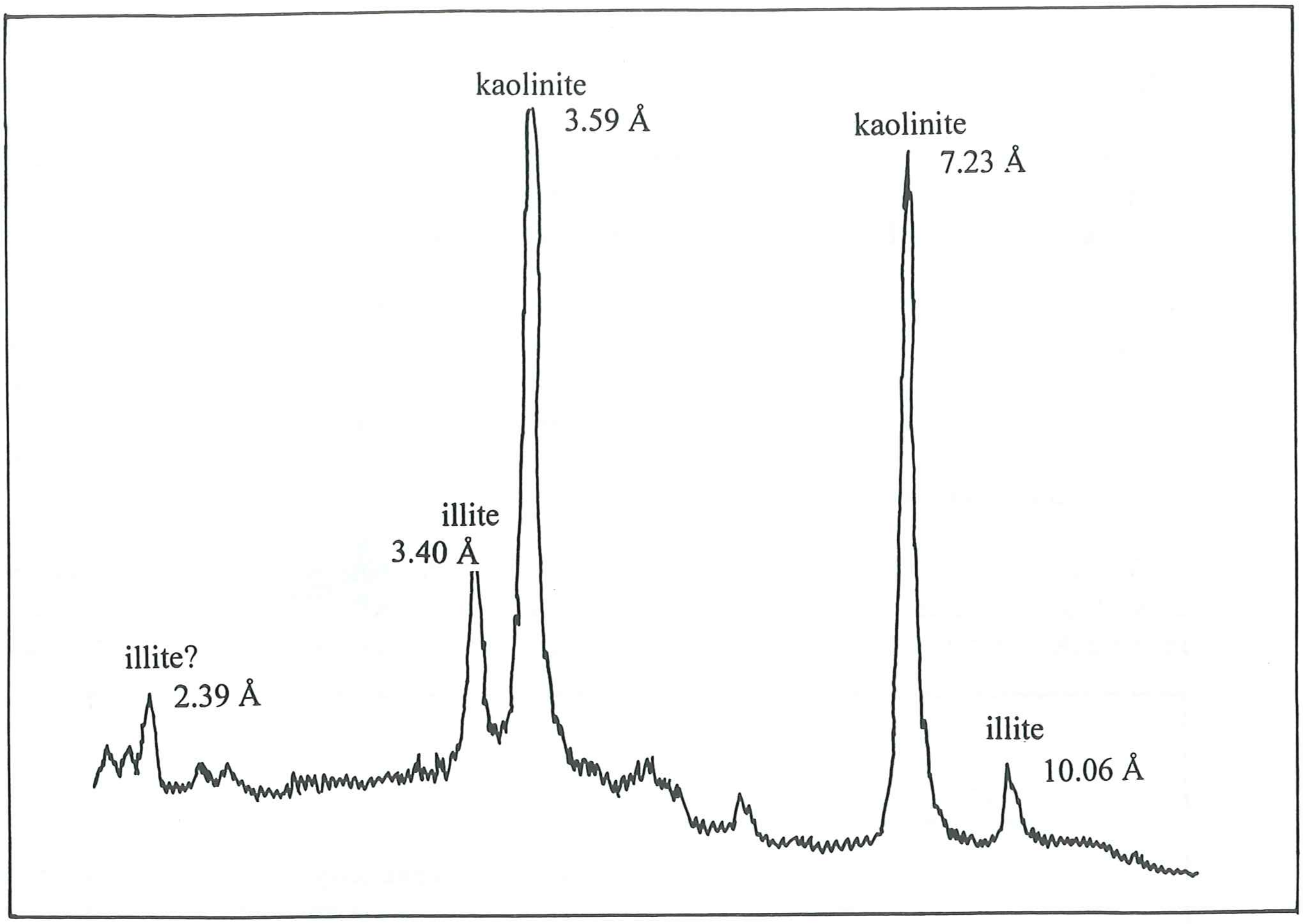


Fig. 11. X-ray diffractogram of the clay minerals of the Fuglunda Member.

Above follow fine sand and organic matter arranged as flaser bedding, which gradually changes to a ripple-drift cross laminated fine sand. At 3.1 m pyrite nodules were found. An increase in average grain size is noticed around 2 m. Following this coarser part of the section a wavy bedded heterolith grade into a flaser bedded ditto. *Diplocraterion* burrows occur between 0.8 and 1.6 m and the sediment consists of ripple-drift cross laminated fine sand with organic drapings at bedding surfaces. Below the coal seam, fine sand with horizontal lamination and rootlets occur. The capping coal seam consists of brittle coal with some clastic content which is decreasing upwards.

Section 3

In the lower part of the section a flaser bedded heterolith, comprising organic matter and fine sand, occurs. Above follows a unit which consists of fine sand showing different sedimentary structures towards the top of the section. The different structures are represented in the sediment in the following order: ripple-drift cross lamination, wavy bedding, flaser bedding and underlying the coal seam horizontal lamination. *Diplocraterion* burrows filled with organic matter occur, as well as organic drapings at bedding surfaces. Roots are reaching down from the coal seam penetrating the upper 0.2 m of the sand. At the base of the coal seam dull coals are dominating, whereas more bright ones are following at the top.

XRD-analysis

The dominating clay minerals of the Fuglunda Member are kaolinite and illite (Fig. 11). Traces of muscovite are present in some samples, possibly due to poor fractionation, whereas no traces of smectite minerals were found.

Petrographic analysis

The dominating mineral, making up the bulk of grains coarser than 0.063 mm in the investigated sections, is quartz. In the three sections the quartz content is ranging from 50 to 98%. Other components present are micas (muscovite), iron minerals and plant fragments. These constituents generally vary at rather low levels (2-10%), though in some samples they act as major sediment contributors. The term iron mineral is beeing used since the intense present weathering makes it impossible to distinguish between pyrite and siderite, especially in the finer fractions. The composition of the sediments at some chosen levels is shown in Figs. 12, 13 and 14.

Section 1 has a variation in quartz content ranging between 30-98 %. The highest values are found in samples from the horizontally

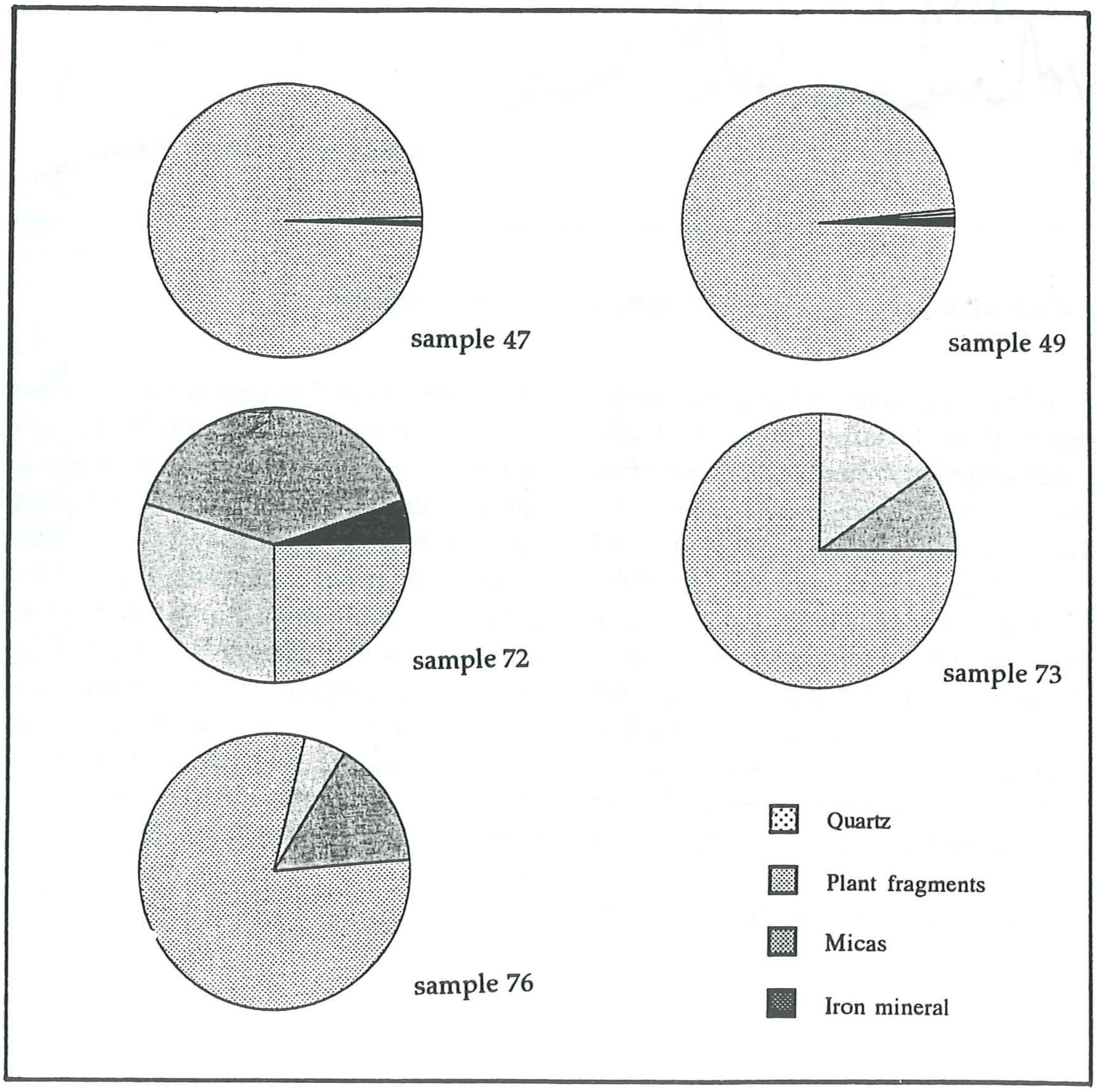


Fig. 12. Composition of samples taken from section 1.

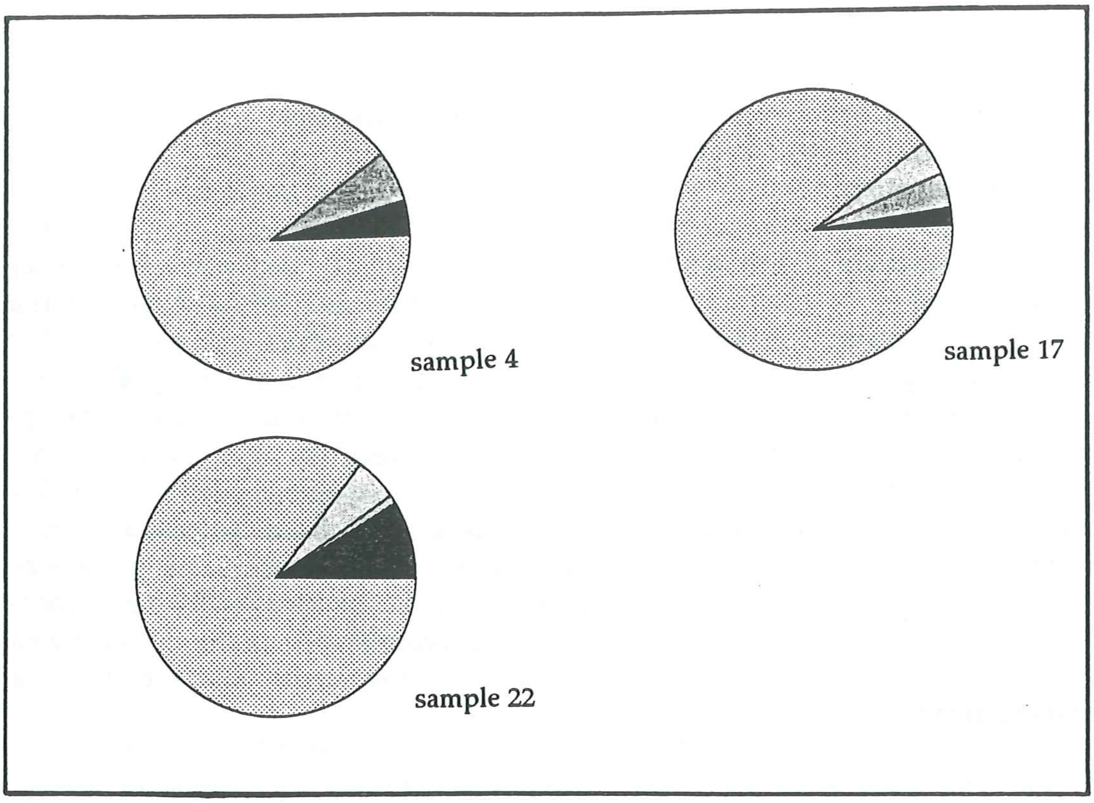


Fig. 13. Composition of samples taken from section 2. For legend see Fig. 12.

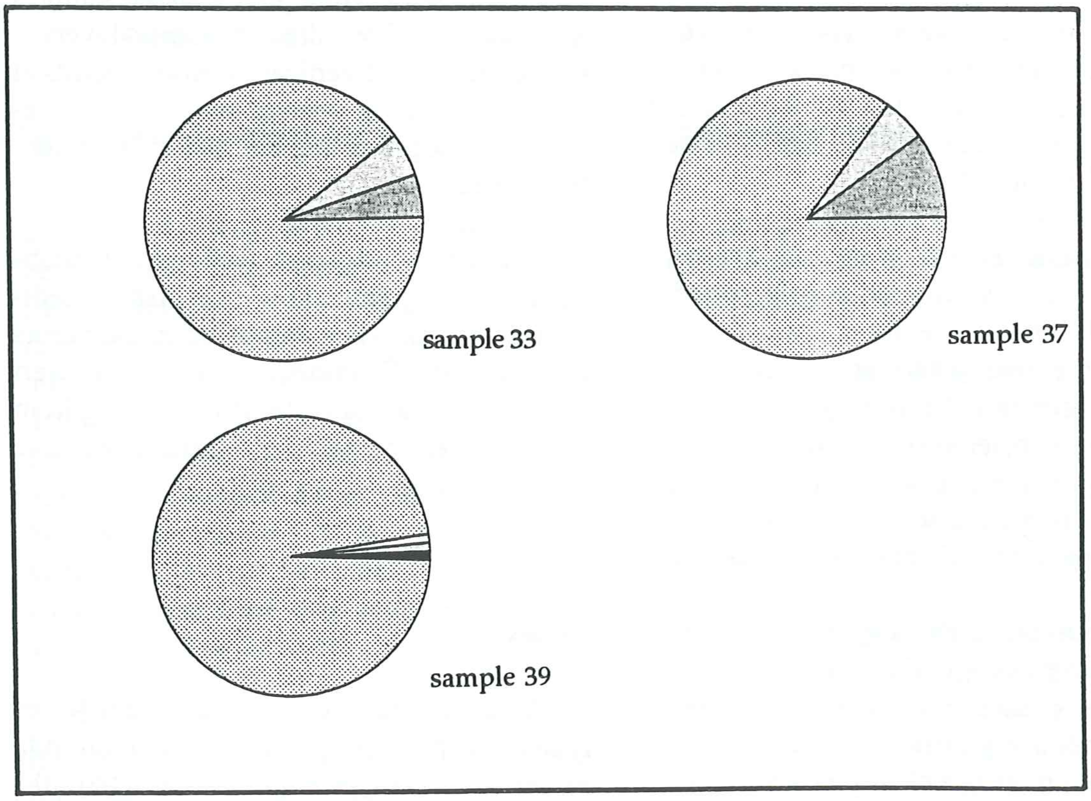


Fig. 14. Composition of samples taken from section 3. For legend see Fig 12.

laminated or ripple-drift cross laminated sand. Samples with lower amount of quartz were taken from the heteroliths and from the coarser basal part of the section. Plant fragments and micas are the secondary components of the sediment. Iron mineral are represented in most of the samples of section 1. The samples of section 2 are primarily consisting quartz (80-98%). Secondary sediment contributors are micas and plant fragments. Iron minerals are present at 0.8 m and 4.5 m. In section 3 the amount of quartz is ranging from 60 to 98 percent. Iron minerals are present in 12 of the 16 samples. Plant fragments and micas are found in almost all the samples.

Grain size parameters

The variation in average grain size of the investigated sections is graphically presented in Figs. 8, 9, and 10.

In section 1 the average grain size is fluctuating between 0.8 and 4.3 phi. For section 2 the corresponding value is 3.4-4.0 phi, and for section 3 the average particle size is ranging between 2.0 and 4.1 phi.

The sorting (Folk & Ward 1957) varies in the three sections between poorly sorted to very well sorted. The finer grained cycles between the coal seams are generally well sorted. In section 1 the average sorting of the sediments is lower than in section 2 and 3. Especially in the coarser levels towards the base of section 1 the sorting is low and there is a clear presence of finer particles as well.

In the investigated samples the skewness is ranging between -0.523 and 0.712. Section 1 has approximately half of the samples negatively respectively positively skewed. In section 2 and 3 there is a clear predominance for negative skewness, i.e. more coarse material is present than expected in a normal distribution.

Discussion

Grain size parameters

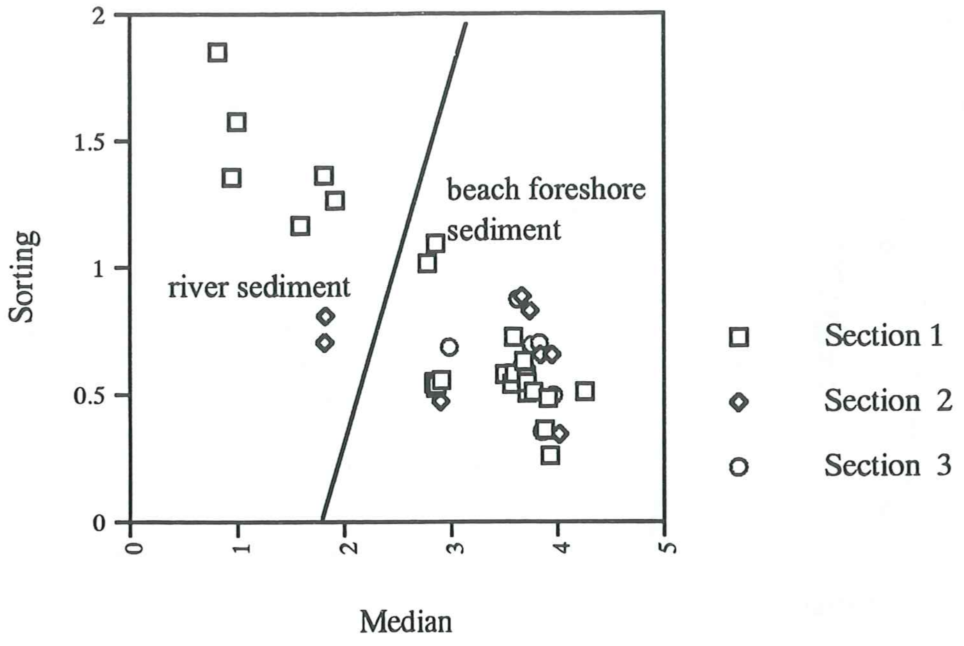
The investigated grain size parameters (average, median, sorting and skewness) have been used to indicate depositional processes active in the formation of the strata, and as a help in the environmental interpretation. The fact that the variation in average grain size is small within the cycles, and with a few exceptions also between the cycles, may indicate either similar depositional processes or different processes, which are competent to transport particles within the same grain size interval. Another explanation for these moderate variations may be a uniform source area prevailing during deposition of the Fuglunda Member.

The spread about the average, i.e. sorting, is at an overall moderate level, with a majority of the samples consisting moderately well sorted fine sand. More poorly sorted samples are generally from distinct coarse layers where the limited vertical extension points at a sudden influx of coarser poorly sorted material into the prevailing fine grained sedimentation area.

For the investigated sections the established scattergrams show two distinct sedimentary types, when compared to the works by Inman & Chamberlain (1955), Stewart (1958) and Friedman (1961), originating from mainly river- respectively beach foreshore processes (Figs. 15, 16, 17).

Facies

As described above two different facies types are prevailing within the Fuglunda Member. In Rolle *et al.* (1979) the heteroliths close to the base of the cycles are referred to overbank flooding, on levées and in interdistributary bays. The interdistributary bays are



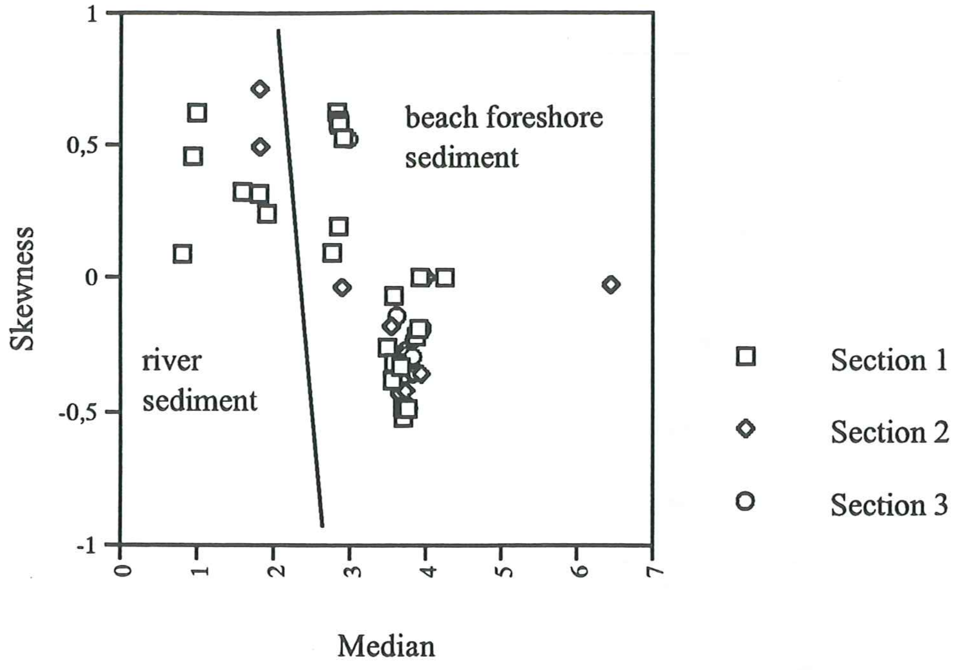
River sediment samples:	**Beach foreshore sediment samples:**
Section 1: 44, 49, 50, 53, 69, 75, 76, 77	**Section 1:** 40, 41, 45, 47, 48, 51, 52, 54, 55, 58, 59, 62, 63, 67, 68, 71, 72, 73
Section 2: 8, 16	**Section 2:** 1, 3, 4, 5, 6, 7, 9, 15, 17, 18
Section 3: 38	**Section 3:** 31, 33, 34, 35, 36, 37, 39

Fig. 15. Scattergram showing sorting plotted against median and the two sediment populations.

defined in Coleman *et al.* (1964) as the areas between the distributaries of a delta, with fresh, brackish or marine shallow water bodies. Whether the bays are open or not, and if they are entirely or partially closed is not included in this definition. In the ripple-drift cross laminated and horizontally laminated fine sand frequent *Diplocraterion* indicate *Skolithos* facies, i.e. littoral sands and highly agitated waters (cf. Seilacher 1963). Possibly these sediments are originating from crevasses into an open bay with marine influence.

Mineral composition show high ratio of fragile components such as micas and plant fragments in the river flood generated sediments, which also indicates a short transport path or a rapid sedimentation process, or a combination of both. In the overlying fine sand the more resistant quartz particles are dominating - possibly suggesting more reworked sediments allowing almost only quartz to be represented in the strata.

The horizontally laminated fine sand is according to Rolle *et al.* (1979) deposited in a beach foreshore environment in the seaward part of a delta, whereas the term ripple-drift cross lamination is not mentioned in their work at all. Parallell lamination in medium- to fine- grained sandstone is produced by flow conditions with high flow velocity and shallow water depth, i.e. an upper flow-regime flat bed mode of transportation either by waves or unidirectional flow (Collinson & Thompson 1989). Differential setting initiated by changes in current velocity or from changes in water chemistry may result in mineral segregation and colour lineation (Coleman and Gagliano 1965). At Eriksdal the presence of



River sediment samples:
Section 1: 44, 49, 50, 52, 53, 54, 55, 59, 62, 69, 75, 76, 77
Section 2: 8, 16, 17
Section 3: 38

Beach foreshore sediment samples:
Section 1: 40, 41, 45, 47, 48, 51, 58, 63, 67, 68, 71, 72, 73
Section 2: 1, 4, 5, 6, 7, 15, 18
Section 3: 31, 33, 34, 35, 36, 37, 39

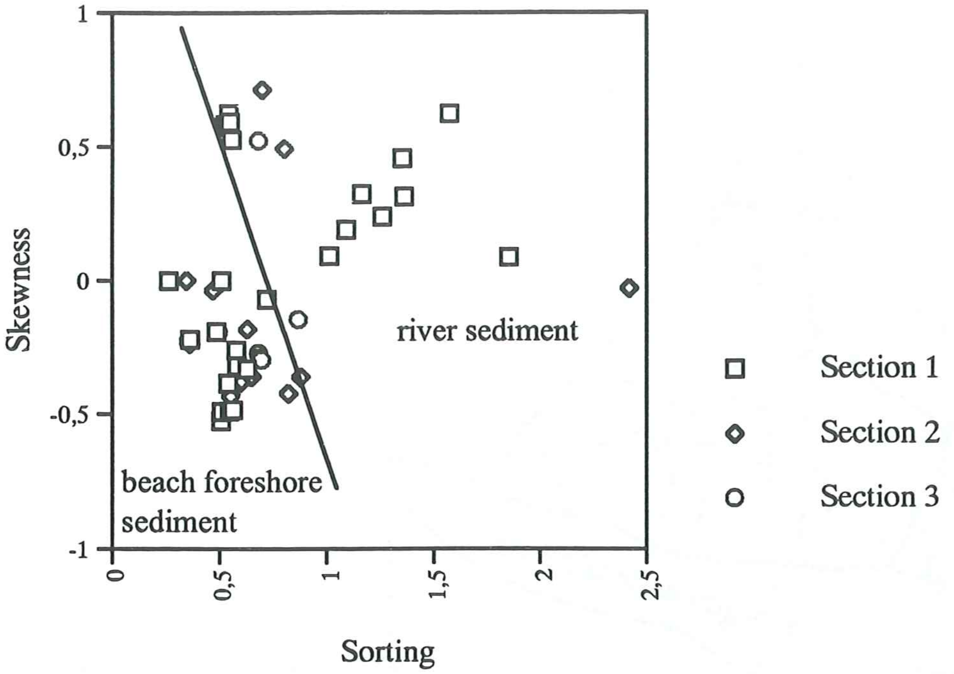
Fig. 16. Scattergram showing skewness plotted against median and the two sediment populations.

undulating lower surfaces, bundled upbuilding, sometimes opposed unidirectional cross lamination and erosive horizons are factors leading to the conclusion that the cross lamination is a result from migrating wave ripples (cf. Collinson & Thompson 1989). A beach foreshore environment is a possible depositional setting for both the ripple-drift cross laminated sand and the following horizontally laminated sand. A relative fall in sea-level may cause the change from ripples to an upper flat bed flow regime with shallower water depth and higher flow velocity.

The lowermost part of section 1, is clearly different from the rest of the member, suggesting a different mode of deposition. These layers of horizontally bedded coarse sand, with gravel concentrated in bands at certain levels, are deposited by river processes according to the established scattergrams. An active distributary channel of the upper flow regime (cf. Tucker 1991) would have been able to produce these structures within the present sedimentary material.

Paleosols

The investigated sections show at different levels diagnostic features of soil formation. Abundant root traces and soil horizons with upper erosional surfaces are common. The coal seams have in most cases coalified rootlets reaching down into the underlaying often darker coloured sand. At other levels of the Fuglunda Member the coal and rootlets are absent. However, there are still traces of soil formation in the form of repeated successions



Beach foreshore samples:
Section 1: 40, 41, 45, 47, 48, 51, 58, 63, 67, 68, 72, 73
Section 2: 3, 4, 5, 6, 9, 15, 17, 18, 19, 20, 22
Section 3: 34, 35, 36

River sediment samples:
Section 1: 44, 49, 50, 52, 53, 54, 55, 59, 62, 69, 75
Section 2: 1, 7, 8, 16
Section 3: 31, 33, 37, 38, 39

Fig. 17. Scattergram showing skewness plotted against sorting and the two sediment populations.

of dark coloured bands with distinct erosional upper boundaries, sometimes with truncated *Diplocraterion* burrows. Downwards the colouring vanishes gradually. Since no traces of vegetation are present, these ancient soils probably never formed the ground for growing plants. They were exposed to the atmosphere and to the climatic factors for a time sufficient enough to start the soil formation, but not long enough to enable the vegetation to get established. A vegetation cover may however been exsisting in the uppermost layer of the paleosol. The plants then altered the texture and geochemistry of the underlying layer before they were eroded leaving no distinct traces of their existence behind. Sediment supply and subsidence may have been controlling factors determining the sedimentation rate and thereby also the possibility of coal and soil formation.

Depositional environment

The presence of coal in a sequence has in many cases been used as evidence for a deltaic environment. It seems however, that most of the active deltas today do not act as potential coal forming sites (McCabe 1984). Still according to Haszeldine (1989) most economic coals do occur in fluvial plain settings often associated with deltas. Thus, in order to classify a sequence as delatic in origin other parameters need to be taken in consideration as well.

Within the Fuglunda Member evidence of marine as well as non-marine conditions clearly suggest a near-shore depositional setting with both marine basinal and fluvial flood generated processes active. Regarding earlier works and the established results of this study

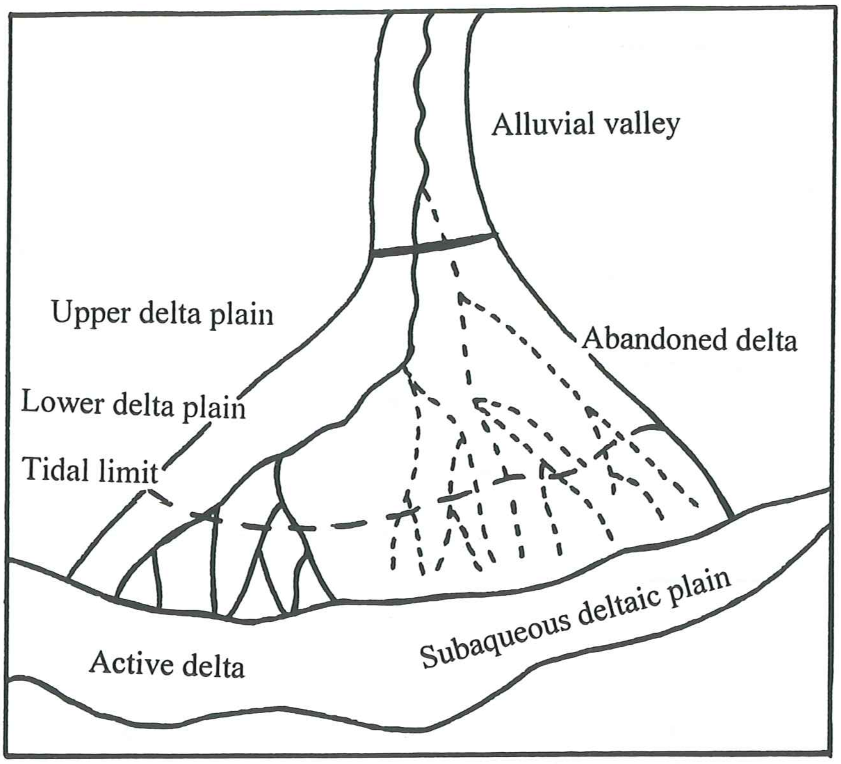


Fig. 18. Morphological zones of a delta plain. (After Wright 1978).

a deltaic setting seems to be a reasonable interpretation of the environment at the locality during the Bajocian.

The flora represented in the coal seams contains cycadophytes, ginkgoes, conifers and ferns, which all are plants growing under fresh water conditions (Tralau 1966). Plant growth and peat accumulation are common features in back-barrier swamps, on overbanks close to channels, and most commonly on water-logged surfaces of abandoned crevasse-initiated minor deltas, lakes and bays of the lower delta plain (Fielding 1984). Accumulation of peat is only able to keep pace with the subsidence and compaction of the underlying sediments for a limited duration of time - eventually the water table rises or falls and either drowns or exposes the swamp entirely. Syndepositional faulting and basement structure are other factors active in determining local coal thickness (Haszeldine 1989). The high ratio of sand in the Fuglunda Member has probably played a role in limiting the vertical extension of the coal seams. The compaction capacity of sand is low compared to more silty and clayish sediments (Haszeldine 1989). The delta plain can be subdivided into an upper and a lower delta plain (Fig. 18), where the lower delta plain is defined as the seaward edge of the delta up to the limit of basinal influence. The upper delta plain is the area situated beyond the reach of basinal processes and extending up to the alluvial plain (Wright 1978). In the lower delta plain the subsidence is more rapid than in the more inland upper delta plain (Hunt & Hoday 1984), leading to different types of coal as a result of the peat accumulation. During rapid burial of organic debris unoxidized bright vitrinite is beeing formed, whereas as subsidence decreases and the peat is better drained more dull coals are produced (Haszeldine 1989). Together with the marine incursions and the fact that the coal seams contains a rather high ratio of bright coals, a lower delta plain environment seems to have beeen the prevailing environment at Eriksdal.

Another evidence for marine intercalations is evident as large pyrite nodules formed eodiagenetically from marine waters. Sedimentary structures such as ripple-drift cross lamination and the presence of calcareous foraminifera (Norling 1972) also points at marine conditions at certain levels. A concentration of pyrite nodules does not necessarily mean a marine depositional environment at that level - marine sulphate may have diffused down through the sediments and then later affected the mineral formation during burial.

The cyclic arrangement of the different types of sediment within the Fuglunda Member and the characteristics of these sediments point, as already suggested, at a lower delta plain environment. In the lower parts of the cycles flood generated processes from the distributaries predominated, and spread clastic grains and organic debris into the interdistributary areas. A relative rise in sea-level lead to exposure of the interdistributary bays to marine basinal influence. *Skolithos* facies, indicated by *Diplocraterion* in the ripple-drift cross laminated sand, is the shallowest marine facies in Seilacher's (1967) study of bathymetry of trace fossils. In Archer and Maples (1984) *Diplocraterion* is characterized as typical for intertidal deposits and in Farrow (1966) especially as dominant of delta top interdistributary bay and lagoonal settings. At Eriksdal the burrows occur at levels where the conditions seem to be transitional from freshwater to more marine ones. Eventually the water depth gradually decreases leading to infilling of the interdistributary bay. After infilling sediment supply may dimish due to upstream avulsion leading to soil formation and possible peat accumulation (Ahlberg 1994). At Eriksdal it seems as if the marine influence and sediment supply vanished and eventually lead to subaeril exposure of the interdistributary areas - peat accumulation and coal formation followed. In many cases there is a considerable duration of time between the deposition of the clastic sediments and the overlying peat (McCabe 1984). However, within the Fuglunda Member the absence of more intense signs of soil formation may lead to the conclusion that at Eriksdal this hiatus of deposition was only of minor extent.

Acknowledgements

I thank my supervisor Kent Larsson for introducing me to the subject and for useful comments to this manuscript. Sophia Gregou most patiently assisted in the preparation and running of the XRD-samples - Thank you! To Jenny Johansson I wish to express my gratitude for excelent support during field work and for beeing such a good friend. At last but not at least I wish to thank my ''ground control'' Mattias Borell for keeping me on the ''right course'' during this adventurous journey and for making my life such a happy one.

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