A backstepping, fluviatile-paralic-marine succession, Sinemurian, Lower Jurassic, Skåne, southern Sweden

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A temporal exposure of a Lower Sinemurian succession of fluviatile, coastal plain and marine sediments was accessible for study during a short time interval in 1997 at Örby, NW Skåne, Sweden. The succession adds significantly to the knowledge and understanding of the Sinemurian sedimentary evolution of the Fennoscandian Border Zone and the north-eastern margin of the Danish Basin. The top of the section overlaps the base of a section previously exposed at the nearby quarry at Gantofta. The combined evidence from Örby, Gantofta and a few borings shows that Sinemurian sedimentation took place during marked stepwise transgression. This is recorded by backstepping of the depositional environments from braided streams, over lakes and swamps, to estuarine and finally fully marine, offshore conditions. The sedimentary packages of the individual systems are well defined and separated mainly by sharp boundaries representing lacustrine, estuarine and marine flooding and ravinement surfaces. A regional sea-level rise punctuated by a minor fall is suggested to be the main factor controlling Early Jurassic basin evolution of the northeastern margin of the Danish Basin and the Fennoscandian Border Zone.

Key words: Sedimentology, petrography, biostratigraphy, sequence stratigraphy, Rya Formation, Döshult Member, Skåne, Danish Basin.

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Knowledge of the Jurassic succession along the north-eastern margin of the Danish Basin is quite fragmentary and is based on scattered, small outcrops and a number of wells. Lower Jurassic deposits are or have been exposed in a few low coastal cliffs in Skåne (Scania) and on the island of Bornholm in the Baltic Sea (Fig. 1). New outcrops exposing poorly known parts of the succession thus add significantly to the understanding of Early Jurassic sedimentary and stratigraphical evolution of the Danish Basin and its north-eastern margin. In the present paper we describe a temporarily exposed Lower Sinemurian succession at Örby in Skåne which is slightly older and overlaps with the base of the classical succession previously exposed at the nearby quarry at Gantofta (Bölau 1973; Reyment 1969a, b; Sivhed 1977, 1980, 1981, 1984; Frandsen & Surlyk in press). The combined Örby-Gantofta section spans virtually the whole of the Sinemurian Stage and allows correlation with other Sinemurian sections in the Tornquist Zone and the Danish Basin. The main aim of our study is to interpret the depositional processes and environments and to constrain the factors controlling Early Jurassic sedimentary development of the area.

Geological setting

The NW-SE trending Danish Basin was formed by rifting in Late Carboniferous-Early Permian times (Vejbæk 1997) and was influenced by Triassic and Jurassic extension and Late Cretaceous-Paleogene

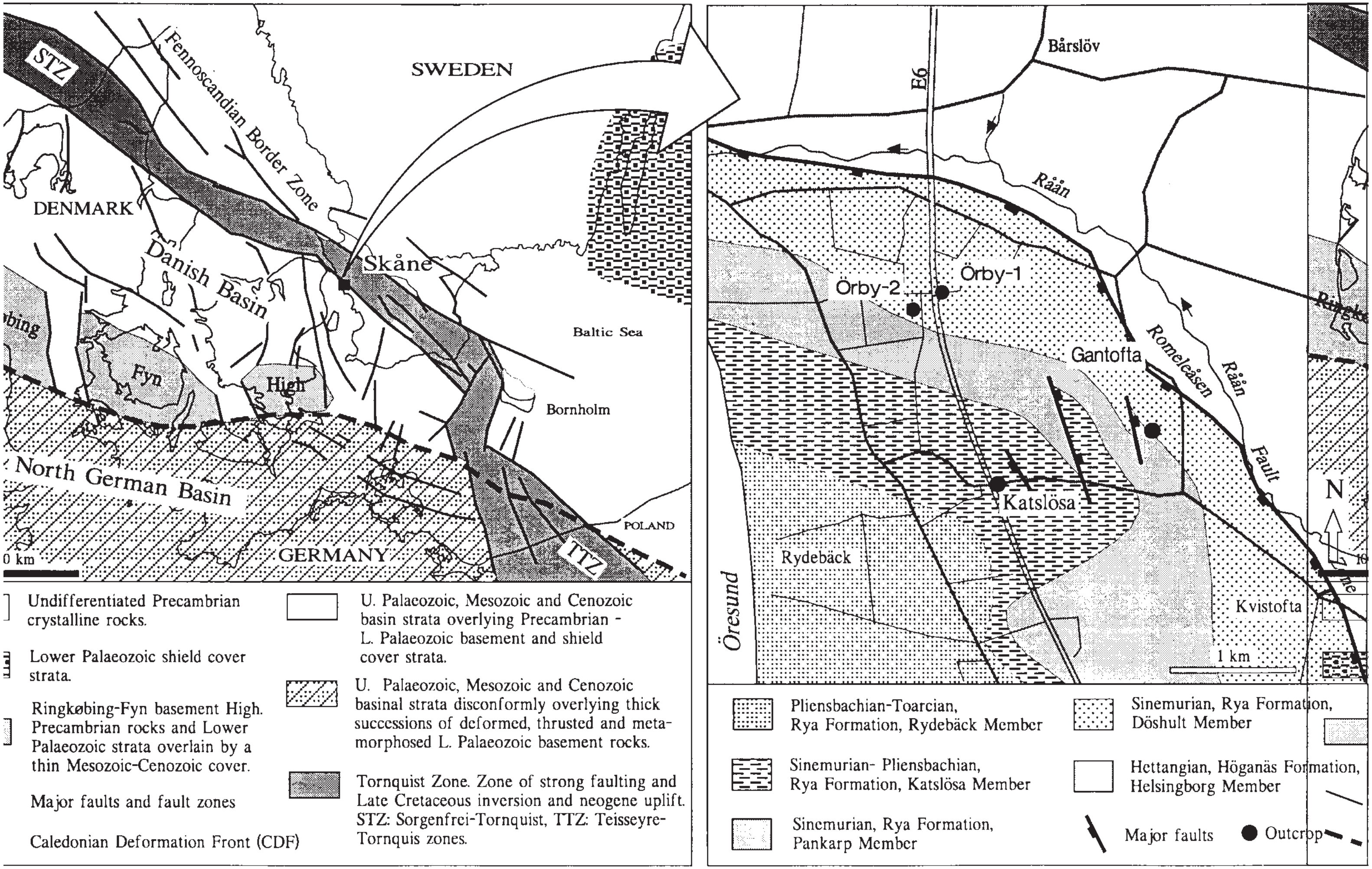


Figure 1. Schematic map of the Danish Basin and surrounding areas showing main structural elements. Enlarged framed area illustrates the location of the Örby 2 locality and the general geology of the area.

inversion (Sorgenfrei & Buch 1964; Liboriussen et al. 1987; Michelsen & Nielsen 1991, 1993; Erlström et al. 1997). The basin is limited to the southwest by the Ringkøbing-Fyn High. The northeastern margin is outlined by the Fennoscandian Border Zone (FSBZ) which is characterised by extensive block faulting along the southwestern margin of the Baltic Shield (Sorgenfrei & Buch 1964; Liboriussen et al. 1987; Thybo 1997). The Fennoscandian Border Zone coincides with the Tornquist Zone in Skåne. The latter splays off in the Sorgenfrei-Tornquist Zone (STZ) which is a distinct, relatively narrow and more northwesterly oriented deep-seated structure characterised by Late Cretaceous-Neogene inversion (EUGENO-S working group 1988) (Fig. 1). Fault movements along the FSBZ and STZ have occurred repeatedly since Late Palaeozoic times and several Triassic and Jurassic extensional episodes are recognised. The late inversion tectonics have, however, created a horst and graben topography which obscures the older Palaeozoic and Mesozoic fault patterns (Norling & Bergström 1987; Michelsen & Nielsen 1991; Mogensen 1994; Michelsen 1997; Erlström et al. 1997). An extensional tectonic regime dominated during the Jurassic and resulted in a mosaic of fault-bounded blocks which strongly affected the depositional style and preservation of strata along the northeastern margin of the Danish Basin.

In NW Skåne the bedrock surface is dominated by sedimentary rocks of the Upper Triassic-Lower Jurassic Höganäs and Rya Formations with a total thickness of around 500 m (Sivhed & Wikman 1986) (Fig. 1). The Quaternary overburden is locally thin and therefore the sedimentary bedrock is commonly exposed by road, tunnel and railroad works.

The new temporarily exposed section at Örby, here named Örby 2, is situated in the northwestern part of one of the main tectonic zones in Skåne, the Romeleåsen Fault Zone. The increased SW dip close to and within this zone is reflected by the southwestward younging of the strata from Middle Jurassic to Paleogene. The Quaternary overburden increases in thickness in the same direction, and the youngest exposed pre-Quaternary strata in the area are the Pliensbachian Katslösa Member of the Rya Formation. Temporary exposures of this unit were also found 2 km south of Örby 2, in connection with ongoing railway construction.

Örby 2, situated about 300 m SW of the Örby E6 viaduct exposure (Örby 1) of Norling (1972), was exposed in the late summer and autumn of 1997 in connection with construction of a subway to the Helsingborg-Landskrona railway. Immediately after our investigation the section was covered with concrete. The temporary outcrop had a length of around 75 m and the strata dip 25°–30° towards the south-southwest. The exposed section displayed a continuous succession of unfaulted strata with a total thickness of about 33 m (Fig. 2).

Stratigraphy

The Örby succession comprises a lower fluvial (0–15.9 m), a middle paralic (15.9–26.6 m), and an upper marine unit (26.6 m to the top) all belonging to the Döshult Member of the Rya Formation (Fig. 2) (Sivhed 1981, 1984). The lower, sand-dominated part of the Döshult Member has hitherto been known mainly from coastal outcrops at Kulla Gunnarstorp north of Helsingborg, and from wells and small outcrops in NW Skåne (Norling 1972; Sivhed 1980; Norling et al. 1993). The Örby 2 section exposed about 33 m of the lower sandy unit of the Döshult Member and together with the Gantofta section it constitutes a combined section through about 100 m of the member (Frandsen & Surlyk, in press).

A total of 44 samples were taken for sedimentologic, petrographic and biostratigraphic investigations. An ostracode study was carried out on 6, palynology on 10, petrography on 36 and clay mineralogy on 8 samples (Fig. 2).

The ostracode fauna of the Örby 2 samples comprises a very restricted number of taxa, and only three species were recorded and identified (Fig. 3). The fauna is clearly dominated by *Cristacythere betzi* (Klingler & Neuweiler 1959); *Isobythocypris elongata* (Blake 1876) also occurs, and a few specimens of *Polycope cerasia* (Blake 1876) were identified. The faunal composition and very low diversity might suggest marginal marine, slightly reduced salinity conditions (A. Lord, pers. comm. sept. 1997). The fauna clearly indicates the Lower Sinemurian *Cristacythere betzi-Cristacythere crassireticulata* Zone of Michelsen (1975). *C. crassireticulata* was not identified, suggesting that the sediments belong to the lower part of the zone. The *C. betzi-C. crassireticulata* Zone is tentatively correlated with the upper part of the Lower Sinemurian *Arnioceras semicostatum* ammonite Chronozone (Sivhed 1980).

A characteristic fossiliferous, bioturbated muddy sandstone overlain by dark offshore mudstone in the upper unit of the Örby 2 section (29.5-30.5 m in Fig. 2) can be correlated with a similar unit at the base of the Gantofta section on the basis of lithology(Reyment 1969a; Sivhed 1977; Frandsen & Surlyk in press).

A palynological investigation on 10 sampled levels (Fig. 2) performed by M. Vasard Nielsen reveals a terrestrial palynoflora. The palynoflora includes 28 different taxa of algae, spores, non-saccate and saccate pollen (Fig. 3). Freshwater influence is indicated by occassional findings of *Botryococcus* in samples 13, 18, 20 and 34.

Petrographical characteristics

Material and methods

The petrographical investigations are focused on the texture, detrital components, clay mineralogy and authigenic mineralisations. Standard and light micro-

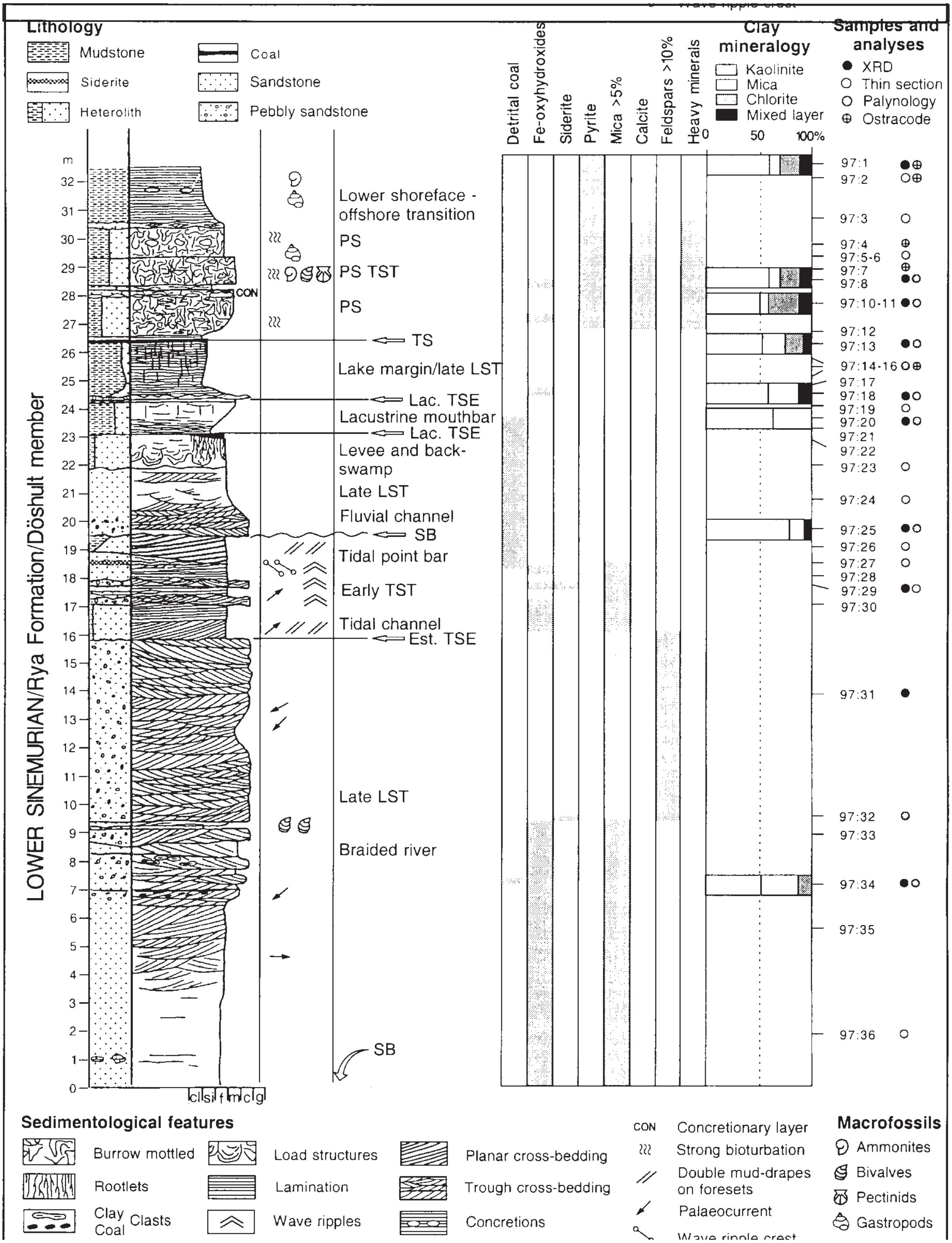
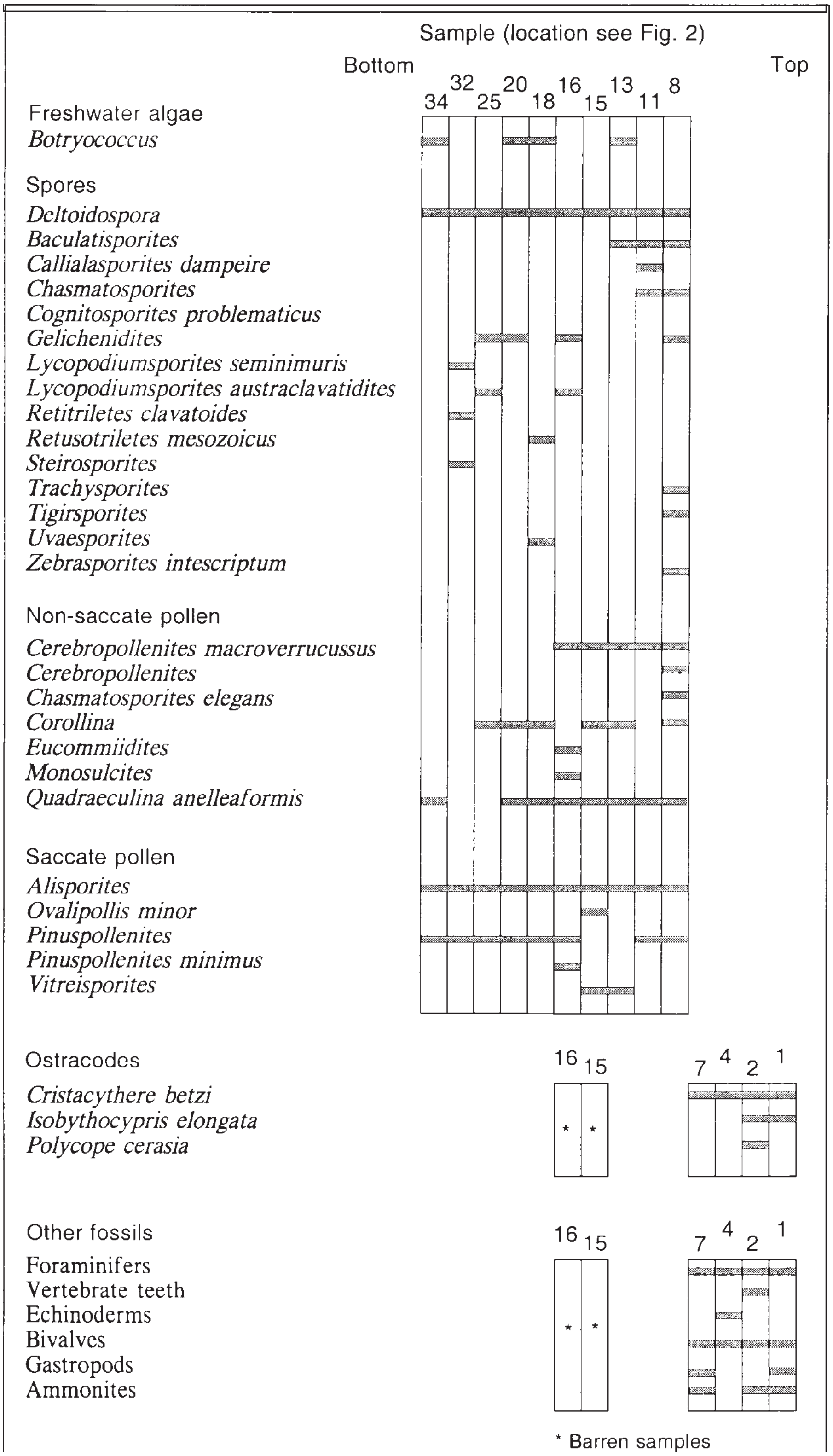


Figure 2. Log of the Örby 2 section showing facies, interpreted depositional environments, sequence stratigraphy, petrography and micropalaeontology. For explanations see text. The sequence stratigraphic terms are abbreviated as follows: SB: Sequence boundary, HST: Highstand systems tract; TST: Transgressive systems tract; TSE: Transgressive surface of erosion; TS: Transgressive surface; PS: Parasequence.

Figure 3. Distribution of palynomorphs, ostracodes and macrofossils observed in the investigated samples (palynomorphs determined by M. Vasard Nielsen).



scopy of hand specimens and thin sections, and powder x-ray diffractometry (XRD) were undertaken.

The lower unit of the Örby 2 section is sand-dominated (below 19.6 m), the middle unit is heterogeneous with sandstone, clay and coal, and the upper unit is dominated by dark muddy sandstone and clay (above 26.6 m).

The deposits are in general poorly consolidated except for two thin ironstone beds in the lower unit and a muddy sandstone in the upper unit. Thin sections of most of the sandstone beds were successfully produced in spite of the difficulties in obtaining undisturbed samples. Standard microscopy was applied on bulk samples from sandstone beds where undisturbed sampling was unsuccessful.

Clay mineralogy analyses were undertaken of a thin clay layer at 7 m, a heterolith at 19.5 m, an argillaceous bed at 23.2 m, a black plastic clay layer at 24.4 m, a heterolith with rootlets at 26 m above a coal layer, a muddy sandstone at 27.5 m, a black clay at 28.2 m and a dark grey clay at 32 m. Additional XRD-analyses were performed on samples from the sandstone beds at 13.5 m and 19 m, and an ironstone bed at 17.5 m. A summary of significant petrographical characteristics is given in Figure 2.

Texture and general lithological characteristics

The yellowish brown sandstones in the lower part of the section (below 9.2 m, Fig. 2) are predominantly fine-grained and characterized by subangular grains (Fig. 4A). Parallel alignments of elongated grains are common. The matrix consists of argillaceous detritus and Fe-oxyhydroxides, and makes up between 5 and 15% of the sediment.

The sandstone beds between 9.2 and 15.9 m are light grey, medium to coarse-grained with numerous white spots of weathered feldspars and display slightly higher textural maturity than the underlying beds. The matrix content is somewhat lower than in the underlying beds, in the range of 5–10%.

The 15.9 and 19.6 m interval is dominated by fine-grained, relatively well sorted laminated sandstones with subrounded grains and coarse-grained occasionally pebbly interbeds. Mica is abundant and is commonly enriched in thin laminae. The deposits are locally enriched by iron minerals (Fe-oxyhydroxides).

Well indurated reddish brown clayey ironstone layers occur at 9.2 and 17.5 m, and are composed of goethitic, originally siderite-cemented, quartz arenites (Fig. 4B). Clasts of consolidated mud and moulds from dissolved bivalve shells occur in the upper part of the bed at 9.2 m (Fig. 4C).

Poorly consolidated fine- to medium-grained and relatively well sorted sandstones make up the interval between 19.6 and 22 m underlying a 1.2 m thick heterolith. The textural maturity is slightly higher than in the underlying units. The interval between 23.2 and 26.6 m is dominated by argillaceous lithologies and very fine-grained sandstones.

The original sedimentary structures of the muddy sandstones between 26.6 and 30.3 m are more or less obliterated by burrowing most likely of an original heterolithic deposit. The sand component consists of a wide range of grain-sizes and the coarser grains are very well rounded.

Fecal pellets (<50 µm) are common in the mudstone. Many are surrounded by a concentric ooid-like coating of light green and brownish mineralisations, probably chamosite-berthierine, suggested by the XRD-analyses (Fig. 4E). The mottled dark grey, brownish and greenish muddy sandstones are occasionally well cemented by a ferrous, clayey calcite. Calcitic bivalve shell fragments are common.

The muddy sandstone (Fig. 4F) is topped by a concretionary layer of mottled green-grey-light brown medium-grained sandstone with a greenish clay-rich matrix and a microsparitic calcitic cement. The coarse grains are well rounded and mainly composed of monocrystalline undulose quartz similar to the sand component in the underlying muddy sandstones (Fig. 4E).

Detrital mineralogy

The Örby 2 sandstones range from quartz arenites to subarkoses. The framework grains are dominated by monocrystalline quartz with undulose extinction. The feldspar content is generally around 5%, but 10-15% between 9.2 and 22 m. The feldspars in this interval are heavily kaolinised. Composite quartz and rock fragments occur in subordinate amounts throughout the section. Muscovite is common in the fine-grained sandstones below 9.2 m and in the interval between 15.9 and 19.6 m. The amount decreases markedly above 19.6 m. The mica is affected by chemical weathering (Fig. 4D), especially in the yellowish brown, iron-enriched sandstones.

The heavy mineral content is generally very low (<0.5%). Slightly higher abundances are observed in the muddy sandstones between 26.5 and 30.3 m and in the concretionary sandstone at 30.3–30.5 m. The heavy mineral suite is dominated by zircon and opaque iron minerals (ilmenite and magnetite). Fine coal particles are abundant in the sandstones between 19.6 and 24.4 m.

Cement and authigenic mineralisations

Most of the sandstones are friable or poorly consolidated. Cement occurs in the variably indurated muddy sandstones, in the ironstone layers and to some extent also in the yellowish brown sandstones in the lowermost part of the section. The ironstones at 9 and 17.5 m were originally cemented by siderite which has been more or less replaced by goethite. The poorly devel-

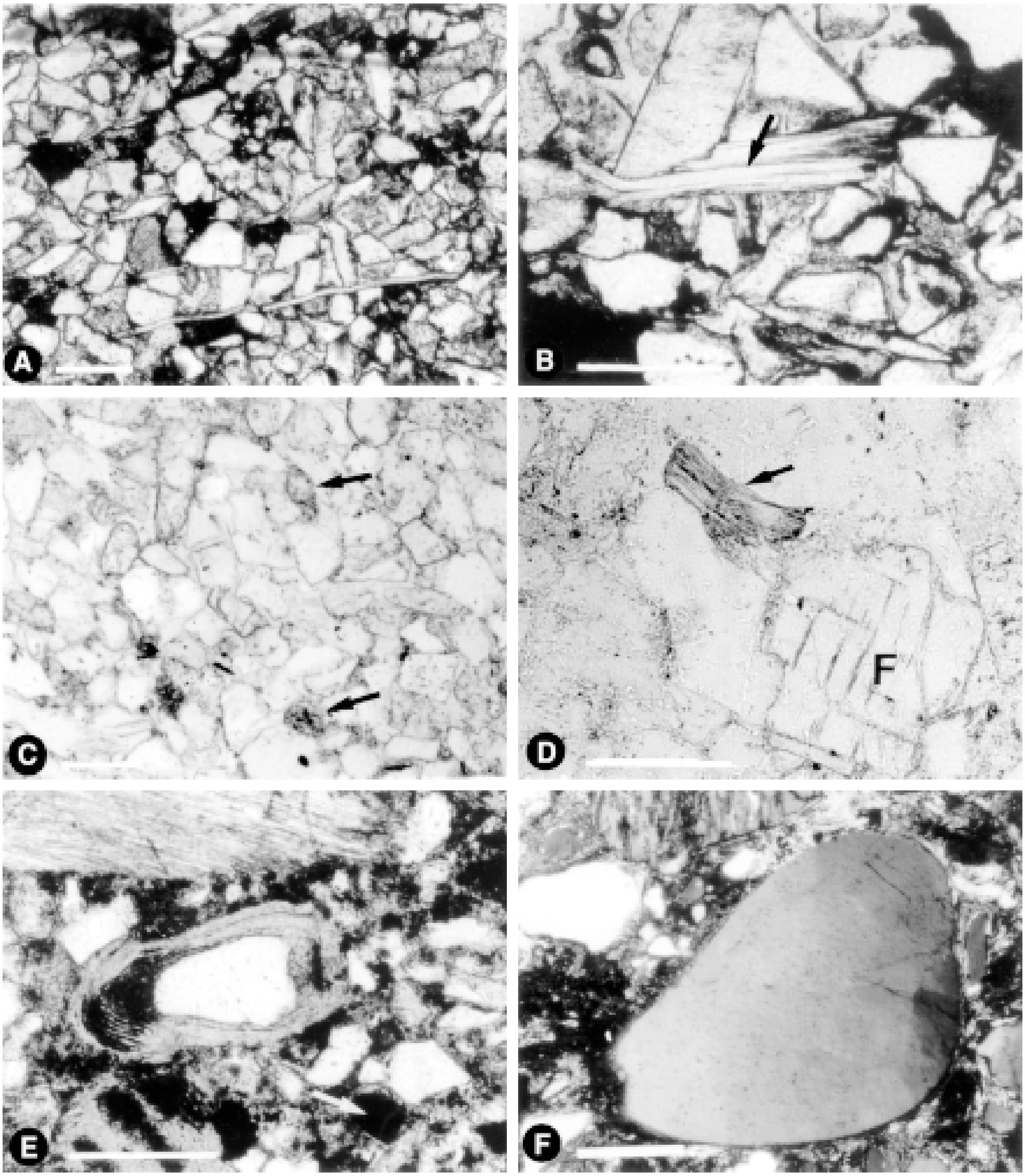


Figure 4. Microphotographs of thin sections from the Örby 2 section. Scale bars = 0.5 mm. A: Fine-grained ferrugineous quartz arenite, typical for the lower part of the section below 9.2 m, plane light (1.8 m, Ö97-36). B: Medium- and coarse-grained quartz arenite with weathered mica (arrow) and associated Fe-mineralisations (black patches), plane light (17.5 m, Ö97-29). C: Subarkose, with numerous weathered feldspars (arrows), plane light (20.2 m, Ö97-24). D: Coarse-grained subarkose with weathered mica (arrow) and feldspar (F), plane light (17.9 m, Ö97-27). E: Concentric ooid-like coating of light greenish and brownish authigenic berthierine-chamosite mineralisation around quartz grain in a sandy mudstone at 28.6 m, plane light (Ö97-5). The sediment is relatively rich in clay mineralised faecal pellets, seen as dark irregular patches. Euhedral heavy minerals are relatively common (arrow). A large calcite shell fragment occurs in the upper part of the picture. F: Sandy mudstone at 30.3 m (Ö97-3), polarized light. Example of coarse, very well rounded monocrystalline quartz grains with undulose extinction which commonly occur in the sandy mudstone facies between 26.6 and 30.5 m.

oped cement in the lower yellowish brown sandstones consists of Fe-oxyhydroxides which mainly occurs as meniscus cement between the framework grains. The source of iron seems to some extent to be related to in situ altered mica. The muddy sandstones are variably indurated by a ferrous clayey microsparitic cement.

Authigenic mineralisations include minor amounts of pyrite in the muddy sandstones and in the septarian nodules in the uppermost clay interval. The nodules are 10-20 cm long and consist of iron-rich and calcareous clayey material with concentric fissures filled with microspar and microcrystalline quartz. Authigenic greenish clay occurs in the muddy sandstones and most likely consists of chamosite-berthierine (Fig. 4E). The mineralisations probably derive from early chemical alteration of fecal pellets in combination with brine pore water. The kaolinite matrix in the sandstones between 9.2 and 19.6 m is to a large extent the result from internal sedimentation from *in situ* weathered feldspars (Fig. 4C). Bulk analyses of the sandstone at 14 and 19 m show a predominance of potassium feldspars over plagioclases. X-ray diffractometry on the ironstone bed at 17.5 m verifies a goethitic quartz arenite with a small amount of siderite. Bulk analysis of the muddy sandstone shows small amounts of pyrite and calcite.

Clay mineralogy

The clay mineral suite is dominated by well crystallized kaolinite (Fig. 2). Micaceous 10 Å minerals are present in significant amounts in all samples except for the uppermost two. The 10 Å minerals are predominantly composed of mica, based on narrow and well defined 001-peaks without expandable interstratified components. The main stratigraphic change in the clay mineralogy is an increasing amount of mixed-layer and chlorite minerals in the samples above a heterolith at 26 m. Bethierine and chamosite are present in the muddy sandstones. These minerals are related to the greenish mineralisations of fecal pellets and ooid-like coatings around detrital grains. A small amount of iron-rich chlorite is also found in the lowermost clay layer at 7 m.

Petrographical conclusions

The general lithological characteristics compare well with what has previously been recorded for the Döshult Member in borings and outcrops in the area (Sivhed 1981, Norling et al. 1993). The succession at Örby 2 is the so far best exposure where the transition between the sandy and clay-dominated facies has been observed. The sandstones in the basal part of the section are dominated by quartz arenites and subarkoses showing moderate sorting and maturity. The content of weathered feldspars increases markedly in the subarkoses between 9.2 and 24.4 m. The high amount of weathered feldspars and predominance of kaolinite in the clays indicate a hinterland area becoming increasingly affected by chemical weathering in a humid and warm climate. However, the total amount of kaolinite occurring in the Lower Jurassic deposits along the Fennoscandian Border Zone is too high to be solely the result of contemporaneous weathering of crystalline provenance areas. It has been suggested that parts of the kaolinite may derive from erosion of a Carboniferous regolith (see Surlyk et al. 1995). The pre-existence of Carboniferous continental deposits along the margins of the Baltic Shield are indicated by the findings of Carboniferous spores reworked into Jurassic and Cretaceous deposits in Skåne and on Bornholm (Guy-Ohlson et al. 1987; Nielsen & Koppelhus 1991; Erlström & Guy-Ohlson 1994). The abundance of kaolinite can thus not be directly used as an indicator of contemporaneous chemical weathering.

The predominance of subangular-subrounded grains and a high number of prismatic and elongated grains in the lower two thirds of the succession corroborates the facies interpretation of a braided river environment. The detrital mineralogy of the muddy sandstones above 26.6 m shows significantly higher mineralogical maturity indicating longer periods of reworking by waves and currents. The undulose extinction of most quartz grains indicates that stressed igneous rock domains constituted the bulk source for the sediments. No indications of sedimentary sources have been found.

The deposits do not show any sign of significant diagenetic alteration. Bending of elongate mica around detrital quartz (Fig. 4B,D) indicates minor compaction and shallow depths of burial. Carbonate cementation, weathering of mica, precipitation of iron, and authigenic clay mineralisation indicate very early diagenetic processes.

Sedimentary environments

A succession of facies associations is recognized in the Örby 2 section (Fig. 2). They are described below in stratigraphically ascending order under the headings of the interpreted environments, in order to ease reading. Each association forms a well defined package bounded by mainly sharp surfaces and corresponds to a major depositional environment.

Braided river association

The lower 16 m of the section consists of trough cross-bedded fine-grained to coarse-grained sandstone showing an overall coarsening-upward trend. Three units from 0–7 m, 7–9.2 m and 9.2–15.9 m are recognized.

Their boundaries are marked by a coaly lamina, 0.5 cm thick, and a fat, grey clay bed, up to 10 cm thick, respectively. The coaly lamina wedges out over a relatively short distance, whereas the clay bed passes laterally into a unit composed of two clay ironstone beds separated by sandstone.

The bulk of the lower sandstone unit is very fine to fine-grained and the top 0.5 m rapidly grades into medium-grained, pebbly sandstone. Bedding is rather poorly defined. The lower part of the unit appears massive with some irregular horizontal lamination, whereas the upper part displays trough cross-bedding with set thicknesses between 0.4–1.5 m. Palaeocurrents could not be precisely measured; the lower part (0–7 m) seems to show an overall eastwards transport direction, whereas the top bed at 7 m shows a clear southwestward palaeocurrent direction. The middle unit (7–9.2 m) consists of alternating medium and coarse-grained pebbly sandstones with light-grey clay clasts, up to 30 cm long and subhorizontally oriented. The upper unit (9.2–15.9 m) varies between medium and coarse-grained pebbly sandstone and does not show any vertical grain-size trend. The average cross-bed set thickness is about 0.50 m. Palaeocurrent directions are mainly towards the southwest.

The immature petrography (see above), the lack of body and trace fossils, and the rather uniform large-scale, trough cross-bedded pebbly sandstones suggest deposition in high-energy probably braided streams. The overall coarsening-upward trend of the three units may reflect long-term tectonic uplift of nearby source areas along the faulted basin margin, climatic change or just random change related to channel width. Lateral shifts and abandonment of the channel systems is reflected by the coaly lamina at 7 m, the clay and clay ironstone beds at about 9 m, and by the reworked clay clasts. The bivalve moulds found in a clay ironstone bed at 9.2 m could not be determined and thus do not give any indications of freshwater or marine influence.

Tidal channel association

The braided river pebbly sandstones are sharply overlain by a low-angle cross-bedded and horisontally laminated, fine-grained sandstone with foresets and laminae draped by mica-rich clay (15.9–17.1 m in Fig. 2). In some cases the drapes are double and are separated by a sandstone lamina, 2–4 mm thick. This bed is overlain by horizontally laminated fine-grained sandstone with several layers of coarse-grained wave-rippled sandstones (17.1–19 m in Fig. 2). Ripples are externally symmetrical and internally asymmetrical with a dominant migration direction towards the northeast. Wave ripple crests at the top of the unit are clay draped and trend NW-SE. It is overlain by a wedge-shaped cross-bedded unit, up to 1 m thick, with clay draped foresets (19–19.5 m in Fig. 2).

The lower part of the unit (15.9–17.1 m in Fig. 2) is tentatively interpreted as subtidal channel deposits on the basis of the single or double mud draped foresets and horisontal laminae. The overlying sharp-based pebbly sandstone beds were deposited during storms and were reworked by waves when the storm faded. The fining-upward cross-bedded heterolith at the top represents a classical tidal point-bar (e.g. Thomas et al. 1987).

Fluvial channel, levee and backswamp association

The tidally-influenced deposits are overlain by an erosionally-based, cross-bedded, coarse-grained, pebbly sandstone grading upward into fine-grained sandstone (19.6–23.2 m in Fig. 2). This is followed by a 1.2 m thick sandy heterolith showing load casts and bleaching overlain by a coal bed, 0–15 cm thick, with branching rootlets, up to 1 m long, descending from its base. There are no rootlets where the coal has wedged out (Fig. 2).

The upward-fining cross-bedded sandstone is interpreted as deposited in a fluvial channel. The bleached load casted top bed represents the levee with soil development followed by thin backswamp peat deposition.

Lacustrine mouth bar association

The levee-backswamp deposits are overlain by a coarsening-upward heterolith, 1.2 m thick (23.2–24.4 m in Fig. 2). It is wavy and lenticular bedded in the lower part and flaser bedded in the upper part with a few low-angle foresets. The association contains the freshwater alga *Botryococcus*. A few rootlets descend from the sharp upper boundary.

The unit is interpreted as a lacustrine mouth bar developed in front of a minor stream.

Lake margin association

The lacustrine mouth bar unit is overlain with a sharp, erosional boundary by a 10 cm clay bed followed by a 10 cm thick coarse-grained, pebbly sandstone with a wave-rippled top. It is overlain by a heterolith, 2 m thick, composed of alternating clay and very fine-grained sandstone laminae showing a lower fining-upward followed by a gentle coarsening-upward trend. Long, densely spaced rootlets descend from all levels in the unit, including the top surface. A thin coal bed overlies the heterolith (26.5–26.6 m in Fig. 2).

The coarse-grained pebbly sandstone at the base of the unit was formed by strong wave erosion during lacustrine flooding of a low lying area. Maximum deepening of the lake, corresponding to the change from fining- to coarsening-upward trend (24.8 m in Fig. 2), was followed by slow progradation of lake margins and infilling of the lake. A peat swamp was developed over the former lake and is represented by the coal bed.

Marine lower shoreface association

The coal bed is overlain by 10 cm of fat, grey clay followed by three units of strongly bioturbated, fossiliferous muddy grey-green sandstone, where the original heterolithic structure is almost completely obliterated by bioturbation. The three units are separated by sharp, planar erosion surfaces. The lowest of the three units coarsen-upward in the lower part and has a higher sand:clay ratio than the two upper units. Clay ironstone concretions occur at several levels and form discontinuous beds at the top of the lower unit and in the middle of the top unit. The dominant trace fossil is *Teichichnus* which gives the sediment a characteristic irregular, finely laminated appearance. Body fossils occur scattered and include the oyster *Liogryphaea arcuata*, ribbed pectinid bivalves, gastropods and ammonites.

Deposition took place in the marine lower shoreface to offshore transition zone close to fair-weather wave base. Sedimentation rates were slow as shown by the complete bioturbation. The grain-size motifs and the sharp boundaries between the units indicate initial slow progradation followed by three episodes of drowning and transgressive erosion under overall backstepping of the coastline.

Offshore marine association

A concretionary layer with lenses of coarse-grained, probably wave-rippled lenses of sandstone rests on the sharp and erosional top of the bioturbated lower shoreface units. It is followed by a fining-upward succession of uniform dark grey clay showing indistinct crude lamination. The clay contains ostracodes and scattered ammonites.

Deposition took place under quiet, probably dysoxic, offshore marine conditions.

Regional correlations

From a litho- and biostratigraphic point of view, the Örby 2 section can easily be correlated with other sections through the Döshult Member (outcrops and core sections) in NW Skåne. Comparable sections discussed below are described by Troedsson (1951), Norling (1972), Sivhed (1980), Sivhed & Wikman (1986), Norling & Wikman (1990), Pienkowski (1991), Norling et al. (1993) and Frandsen & Surlyk (in press).

The ostracode fauna dates the uppermost 6 m of the Örby 2 section, interpreted as lower shoreface-offshore transition zone deposits, to the lower part of the Lower Sinemurian *Cristacythere betzi-Cristacythere crassireticulata* ostracode Zone. Strata of the same age and lithology have been found in the very basal part of the Gantofta brick pit (Frandsen & Surlyk in press), the Örby 1 section (Norling 1972) and locality 66 of Troedsson (1951). Comparable strata have also been found in numerous drill cores in NW Skåne (Norling 1972; Sivhed 1980).

Some beds in the upper part of Örby 2 are rich in macrofossils, such as ammonites, oysters, pectinid bivalves and gastropods (Fig. 3). This reminds of the rich macrofauna obtained from locality 66 of Troedsson (1951). The strata between the braided river and the lacustrine units are mainly composed of sandstones with heterolithic beds in the top. Comparable strata have been found in the Örby-1 section of Norling (1972) and in numerous other outcrops in NW Skåne. The most well known localities are Laröd (Norling et al. 1993), Döshult (close to locality 66 of Troedsson 1951), and the “Grindstone locality” at Gantofta (Norling et al. 1993).

Sequence stratigraphy

The Örby 2 section shows an overall upwards decrease in sand:mud ratio and a change from dominantly terrestrial to fully marine deposition reflecting a long-term transgressive development. The lower braided river unit is topped by an erosion surface at 15.9 m (Fig. 2) marking a change from fluvial to tidally-influenced estuarine deposition. The data do not allow a direct sequence stratigraphic interpretation of the fluvial unit. A possible interpretation is that it represents late lowstand filling of an incised valley during initial slow base level rise.

The upper boundary of the fluvial unit is interpreted as a transgressive estuarine erosion surface (TSE) representing the first marked backstepping event. The succeeding estuarine unit (15.9–19.6 m) is interpreted as the early transgressive systems tract. The overlying fluvial unit (19.6-23.2 m) may represent final filling of the estuary during highstand. Alternatively, the sharp erosional base is a sequence boundary (SB) formed during base level fall and the fluvial succession represents the late lowstand systems tract. The latter interpretation is tentatively preferred here.

The sharp top of the fluvial unit at 23.2 m (Fig. 2) was formed by lacustrine transgressive erosion and formation of shallow coastal lakes. Deposition of the overlying lacustrine succession (23.2–26.6 m) took place under slow base level rise and forms the late lowstands systems tracts. The top of the coal at 26.6 m (Fig. 2) is interpreted as the transgressive surface representing marine flooding of the coastal plain. The overlying stacked shoreface-transition zone units (26.6–top of section) form a backstepping parasequence set culminating in dark-grey offshore marine clays at the top of the section and constitute a transgressive systems tract.

The Döshult Member at Örby 2 is thus interpreted as composed of two sequences. The lower sequence boundary is not exposed but the lowest 19.6 m of the succession forms the late lowstand and early transgressive systems tract. It is truncated by the second sequence boundary at 19.6 m which is overlain by a late lowstand systems tract topped by the transgressive surface at 26.6 m. This is followed by a backstepping transgressive systems tract.

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Dansk sammendrag

En blotning af Nedre Sinemurien sedimenter ved Örby i Skåne var tilgængelig i kort tid i 1997. Lagfølgen består af fluviatile, kystslette og marine sedimenter. Toppen af lagserien overlapper bunden af en lagserie, der tidligere var blottet i en nærliggende lokalitet ved Gantofta. Kombinerede data fra Örby, Gantofta og en række boringer viser, at sedimentation i Sinemurien i området fandt sted under en trinvis transgression punktueret af en enkelt regression. Dette forløb afspejles i en tilbagerykning af aflejringsmiljøerne fra flettede flodsystemer over søer og sumpe, til æstuarine og til slut fuldt marine forhold. De sedimentære lagpakker, der opbygger de enkelte aflejringssystemer, er veldefinerede og begrænset af æstuarine og marine drukningsflader eller transgressive erosionsflader. En regional havniveaustigning punktueret af et mindre fald synes således at have kontrolleret tidlig jurassisk bassinudvikling langs den nordøstlige rand af det Danske Bassin og i den Fennoskandiske Randzone.

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