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Forskningsrapporter

Guide to the Upper Triassic and Jurassic geology of Sweden

Erik Norling, Anders Ahlberg, Mikael Erlström and Ulf Sivhed

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Sveriges Geologiska Undersökning
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Cover: Coastal section of the Kulla-Gunnarstorp locality
(excursion locality No. A12). Photo: M. Erlström.

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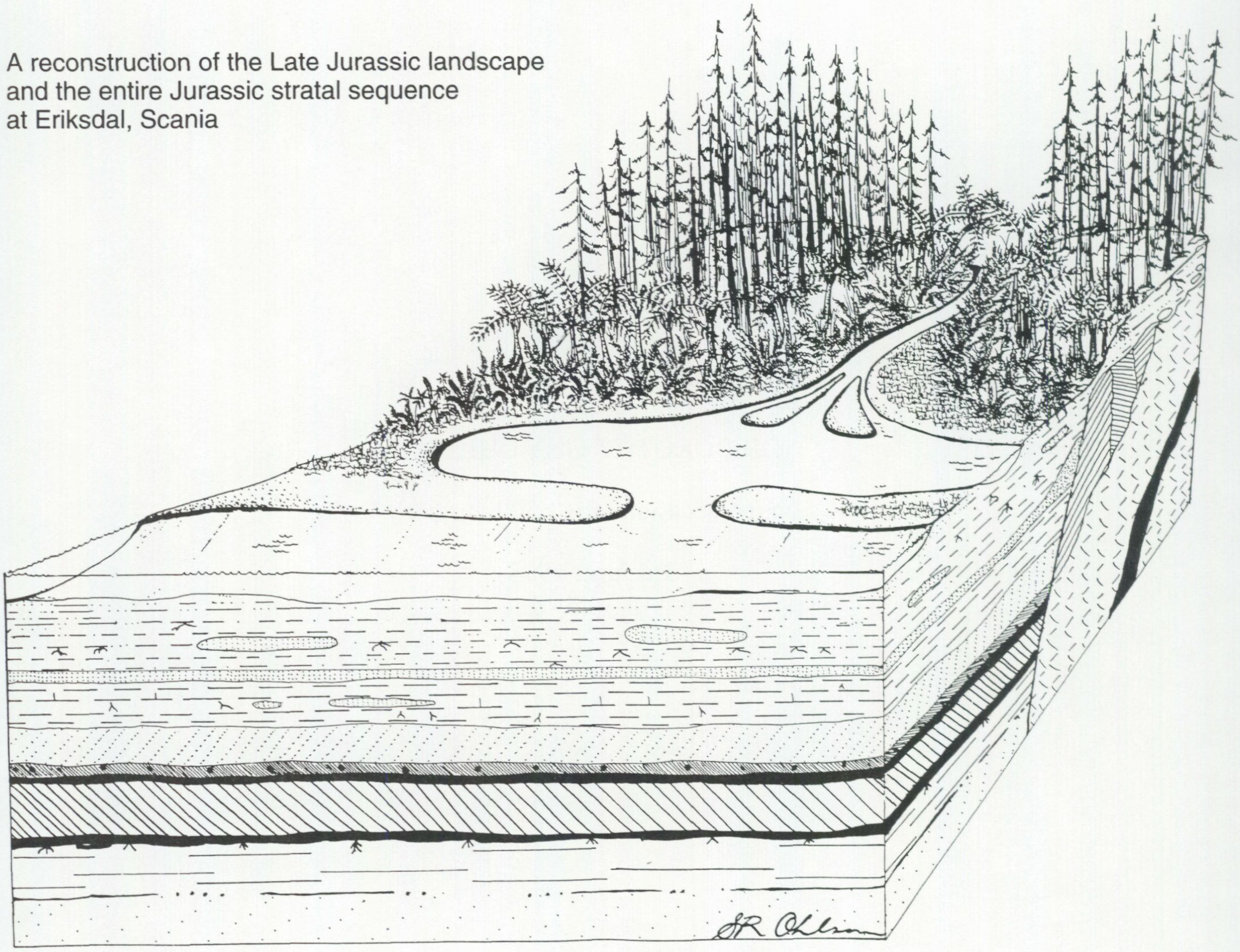
This contribution is humbly dedicated to

DR DOROTHY GUY-OHLSON

on the occasion of her 50th birthday

3rd June, 1993

A reconstruction of the Late Jurassic landscape and the entire Jurassic stratal sequence at Eriksdal, Scania



VITABÄCK CLAYS
(TITHONIAN – BERRIASIAN)
Clay and silty clay with sand lenses and rootlet horizons
Marginal coastal environment

NYTORP SAND
(KIMMERIDGIAN – TITHONIAN)
Mainly pure quartz sand
Sand barrier – strand plain environment

FYLEDAL CLAY
(KIMMERIDGIAN)
Variegated clay and claystone, partly calcareous with rootlet horizons and rare sand lenses. Coastal plain

GLASS SAND
(BATHONIAN)
Pure quartz sand, in part with kaolin
Deltaic deposit

FUGLUNDA MEMBER
(BAJOCIAN)
Silt, sand, clay and coal-seams with rootlet beds.
Flood plain deposits

LOWER JURASSIC – BASAL MIDDLE JURASSIC
(SINEMURIAN – AALENIAN)
Ferruginous sand and sandstone, in part oolitic.
Shallow shelf deposits

LOWER PALAEOZOIC
Sedimentary rocks

PROTEROZOIC
Crystalline rocks with Upper Palaeozoic dolerite dykes

CONTENTS

ABSTRACT

Norling, E., Ahlberg, A., Erlström, M., and Sivhed, U., 1993: Guide to the Upper Triassic and Jurassic geology of Sweden. Sveriges Geologiska Undersökning, Ser. Ca 82, 71 pp. Uppsala 1993. ISBN 91-7158-530-3.

Outcrops of Upper Triassic and Jurassic rocks in Sweden are few and usually of no great extent. This guide-book is produced in order to permit excursion groups as well as individual geologists to familiarise themselves with these geological localities. The introductory part gives an outline of the Upper Triassic and Jurassic geology of Sweden, including palaeogeography, tectonic pattern, volcanic rocks and the sedimentology and diagenesis of the sedimentary deposits. The succeeding chapters deal with the lithostratigraphy, biostratigraphy (ammonite, foraminiferal, ostracodal and palynomorph stratigraphy), industrial minerals and the mining history associated with them. Twenty excursion localities with geological ages ranging from the Late Triassic (Norian) to the Late Jurassic (Tithonian) are described. The excursion localities, situated in the three different areas of NW Scania, Central Scania and the Fyledalen Valley in the southern part of the province, are described under the following subheadings: objective, location, map sheets, coordinates, geological setting, biostratigraphy and characteristic fossils, lithology and lithostratigraphy, sedimentology, diagenesis, and references. The guide aims at providing the field trip geologist with comprehensive and detailed information on Upper Triassic and Jurassic geology in Sweden. In addition to the list of localities recommended a further two visits have been suggested; a ceramic pottery, whose production is based on the local clays and a local museum with exhibitions on mining history and Triassic–Jurassic geology.

Key words: Upper Triassic, Jurassic, field guide, lithostratigraphy, biostratigraphy, sedimentology, diagenesis, volcanism, industrial minerals, Scania, Sweden.

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Fig. 1. Simplified geological map of Scania (After Bergström *et al.* 1988)

OUTLINE OF THE UPPER TRIASSIC AND JURASSIC GEOLOGY OF SWEDEN

In 1982 the Geological Survey of Sweden (SGU) published a geological guide-book entitled "Guide to Excursions in Scania" (Bergström *et al.*, SGU Ser Ca No. 54). It was primarily produced for participants in the 1982 working meeting for the project "East European Platform, SW Border (IGCP Accession No. 86)". Apart from an outline of the geology of Scania, focussed on the Phanerozoic, 10 geological sites representing the Lower Cambrian to Lower Paleocene were described. That guide has been a bestseller for the Geological Survey and is now out of print. The present authors have realized the need of guides to Swedish geology published in English. This guide to the Upper Triassic–Jurassic geology of Sweden is published to honour Dr Dorothy Guy-Ohlson, Swedish Museum of Natural History, on the occasion of her birthday, June 3, 1993. She has been a leading and very enthusiastic investigator of the Rhaetian-Jurassic succession in Sweden for more than two decades. Her field embraces palynology, palaeoecology, stratigraphy and palaeogeography.

Geological setting

Upper Triassic and Jurassic rocks are restricted to southern Sweden, to the East European Platform margin, which is characterized by a complex block-faulted zone traversing the province of Scania in a SE–NW direction (Figs. 1, 4). This zone, known as the Tornquist Zone (after a German geologist. See Norling 1981, pp. 163–165), can be followed from the Rumanian Black Sea coast, along the eastern front of the Carpathians, through Poland, the eastern part of Germany, Bornholm, Scania, Kattegatt, N Jutland, up into the North Sea, west of southern Norway. The Scanian part of this zone includes the Precambrian basement, Early Palaeozoic sedimentary strata, Late Palaeozoic dolerite dikes, Mesozoic and Palaeogene sediments and volcanic rocks. During Late Palaeozoic-Mesozoic times Scania acted as a buffer zone between the stable Baltic Shield and the active Hercynian and Alpine tectonic regimes.

Main tectonic lineaments, mostly resulting from Permo-Carboniferous, Late Triassic-Jurassic, and Cretaceous-Palaeogene deformation phases, are shown in Fig. 4.

The Triassic sedimentation was influenced by incipient rifting and block faulting in a NW to WNW trending zone from Scania to north Jutland (Freeman *et al.* 1988). Beneath Denmark the Triassic sediments rest conformably on Zechstein evaporites (Pegrum 1984; Freeman *et al.* 1988). In Scania, however, they onlap Lower Palaeozoic rocks and the Precambrian crystalline basement. In Sweden, strata belonging to the Lower, Middle and lower Upper Triassic are known from southwestern Scania only. The uppermost Triassic, corresponding to the Norian and Rhaetian Stages, however, has a much wider geographical distribution. These deposits, referred to as the Kågeröd and Höganäs Formations (Triassic part) have a combined thickness of more than 300 m.

During latest Triassic times a new period of tectonic activity, of major importance in the structural history of Scania, commenced. This tectonic period is referred to as the Kimmerian phase (*sensu* Stille 1924), which lasted from the Rhaetian until the earliest Cretaceous. The development of the Rhaetian sedimentation appears to have been rather undisturbed, quiet and undramatic. Contemporary with the initiation of the Kimmerian tectonic phase, Scania was subjected to major climatic changes. The variegated sandstones, conglomerates, arkoses and shales of the Kågeröd Formation (Figs. 1, 2), regarded to be of arid and continental origin, were overlain by predominantly dark coloured, coal-bearing, arenaceous and argillaceous sediments of Rhaetian age, formed during humid conditions. The present distribution of Rhaetian and Jurassic sedimentary rocks in Scania and adjacent areas is illustrated in Fig. 6. The volcanic activities ("volcanic area" on the map) are dated as being of both Jurassic and Cretaceous age.

In Scania, strata spanning the Triassic–Jurassic boundary include clayish, silty and sandy, coal- and plant-bearing sedimentary rocks of continental and deltaic character. In W and NW Scania they are referred to the Höganäs Formation (some 250 m thick), which is subdivided into three well defined members (Sivhed 1984 and p. 16 herein). In central and southern Scania the corresponding succession has not yet been properly described from a lithostratigraphical point of view. The warm and humid climate during the Rhaetian and Jurassic caused a deep kaolinisation of the crystalline basement (Norling 1978, Lidmar-Bergström 1982). The kaolinitic Rhaetian claystones are utilized for their excellent ceramic properties (p. 30).

The Rhaetian–Early Jurassic transgressions of the Tethyan Sea, which reached northwards into the Central-Graben of the North Sea and the northwestern part of the Danish Subbasin, did not affect Scania until Hettangian

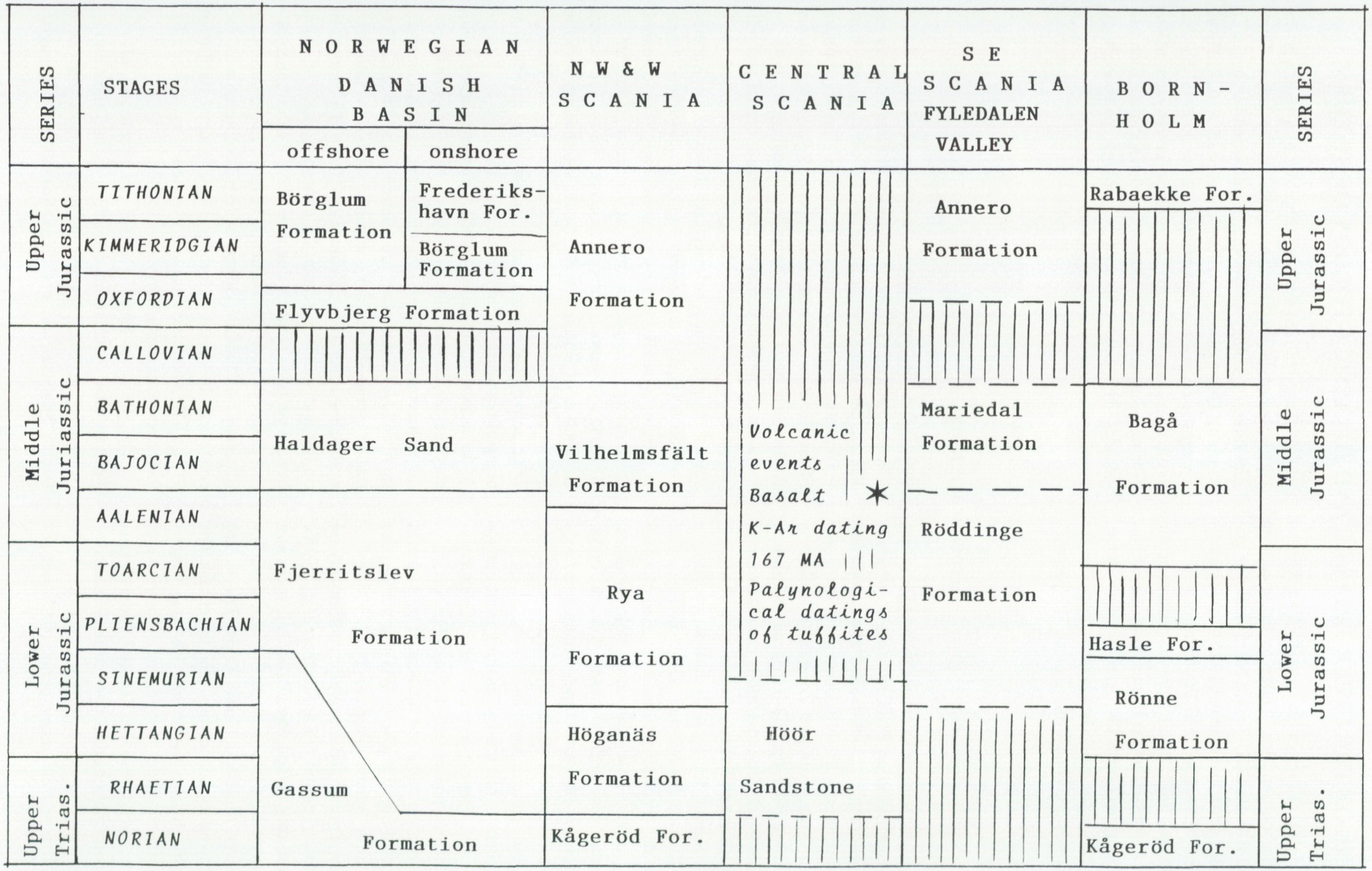
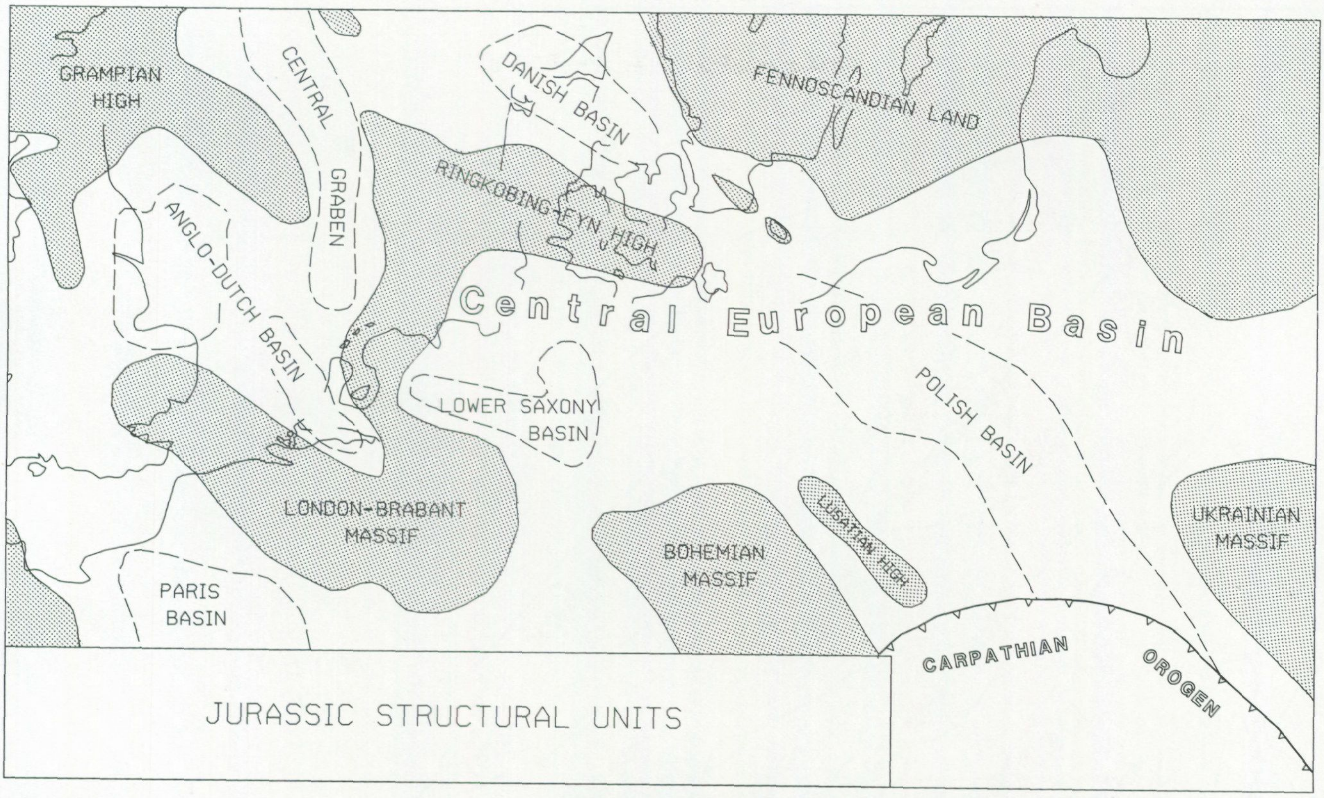


Fig. 2. Upper Triassic and Jurassic stratigraphy of the Norwegian–Danish Basin, Scania and Bornholm (after Michelsen 1978, 1986, 1989; Berthelsen 1978; Bergström *et al.* 1982 Gravesen *et al.* 1982).



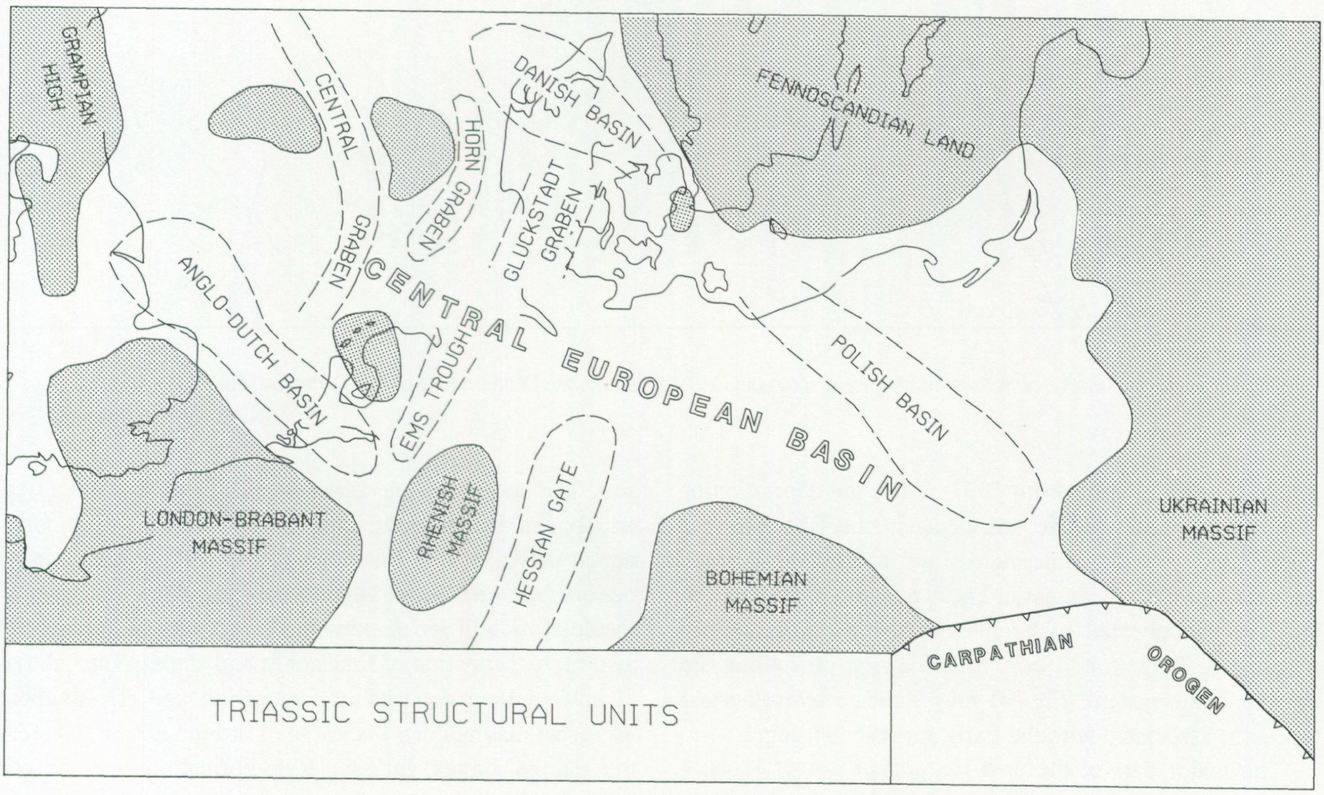


Fig. 3. Triassic and Jurassic structural units at the SW border of the East European Platform.

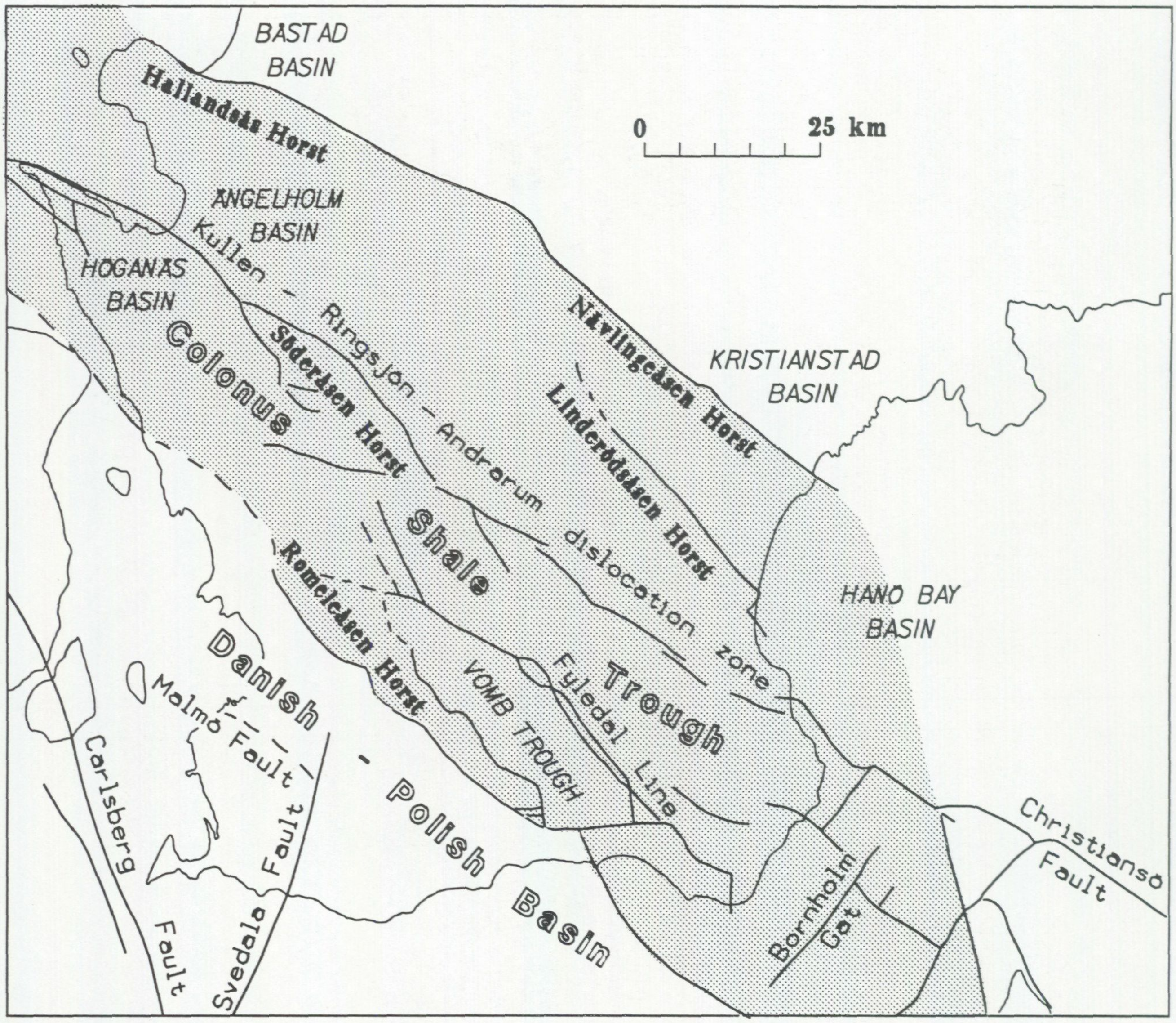


Fig. 4. Structural framework of Scania and adjacent areas (shaded area marks the Scanian part of the Tornquist Zone).

times (Norling & Bergström 1987). After the deposition of mainly continental-deltaic sediments in the Rhaetian and Hettangian, several marine ingressions invaded the Scanian area during the Early Jurassic. These transgressions seem to have been connected with an increased tectonic activity (Norling & Bergström 1987). Sideritic iron ores along the Fyledal Fault system (Fig. 4) may indicate hydrothermal processes associated with the Early Jurassic faulting.

The major part of the post-Hettangian Lower Jurassic succession in Scania is of marine origin. In the western and northwestern parts of the province, marine Lias is referred to the Rya Formation (Norling 1982). The first major Jurassic transgression appeared in Early Sinemurian time and formed the Döshult Member (pp. 18, 22), which is characterized by coarse, cross-bedded sandstones and siltstones in the lower part and silty claystones and marls in the upper part. The latter beds are relatively rich in marine biota (e.g. ammonites, brachiopods, foraminifers). After a short continental period in mid Late Sinemurian time, a long marine period followed (Late Sinemurian–Toarcian), resulting in the deposition of ferruginous sandy and silty sediments, but also in the formation of limestones and shales. The "alluvial end" deltaic deposits of Hettangian age (Helsingborg Member) may reach a thickness of around 200 m, whereas the marine Lower Jurassic Rya Formation may exceed 300 m in thickness. The four members included in this formation will be further commented on under stratigraphy and depositional environment sub-headings.

Increasing tectonic activity in the early Middle Jurassic (mid-Kimmerian tectonic phase) caused major changes in the paleogeography and sedimentation patterns of NW Europe (Fig. 5). Such a drastic change was the uplifting of a

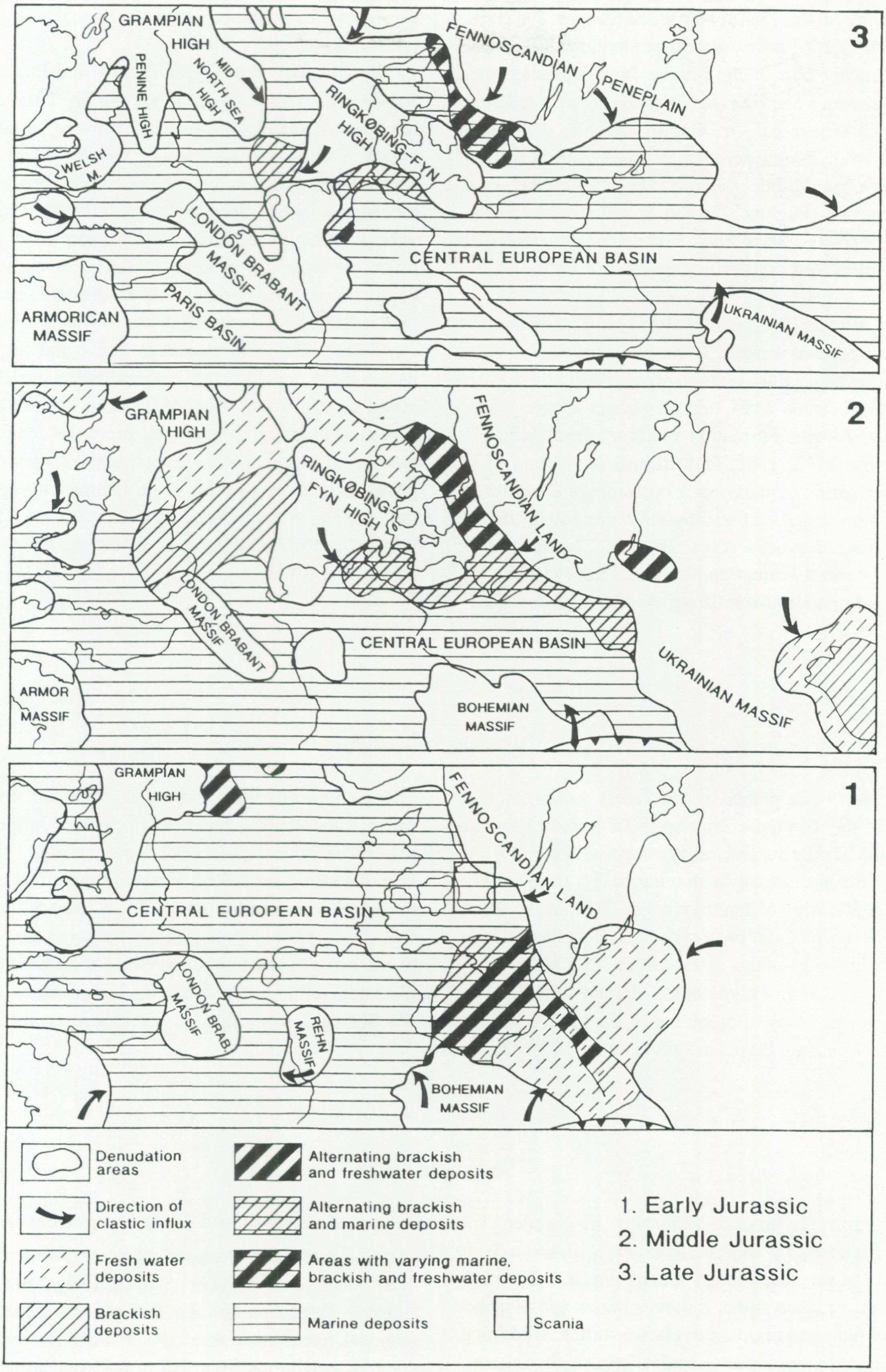


Fig. 5. Palaeogeographical maps of the Jurassic Series (mainly after Jubitz *et al.* 1987, 1988).

large rift dome in the central North Sea (Ziegler 1982). Lacustrine and alluvial environments predominated in Scania during the major part of the Middle Jurassic, though thin marine ingressions and brackish intervals are also indicated in the stratal sequences. The clayish and silty deposits of the Vilhelmsfält Formation (Fig. 10) are characteristic of the NW Scanian Middle Jurassic. The argillaceous, coal-bearing deposits (Fuglunda Member) and the arenaceous, kaolinitic deposits (Glass Sand Member) characterize the Middle Jurassic of western and south Central Scania (Fig. 10).

In the Callovian, or possibly already in Late Bathonian time, certain parts of western Scania and offshore areas east of Scania (the Hanö Bay) were transgressed by the sea. The truly marine Fortuna Marl (top Bathonian–Lower Oxfordian) of the Annero Formation is known from boreholes only (Norling 1972, 1981; Guy-Ohlson & Norling 1988, 1993). This marine sequence with occasional freshwater influence is represented by fossiliferous, calcareous siltstones with limestone interbeds (Figs. 10, 11). The succeeding part of the Annero Formation, known as the Fyledal Clay, Nytorp Sand and Vitabäck Clays, was formed in depositional environments regarded as typical marginal facies (Erlström *et al.* 1991, 1993).

The distribution of Upper Triassic and Jurassic rocks in Sweden is illustrated by Figs. 6a and 6b. Their distribution has been affected by Kimmerian, but also by later tectonic events. During the Kimmerian tectonic phase along the southwestern margin of the Fennoscandian Shield, the movements were characterized by sinistral (left-lateral) wrench faulting and tension. In Late Santonian–Campanian times an inversion process started as a consequence of compressional deformation. Transgressed areas became land and deeply submerged deposits were subjected to erosion. Basins became structural highs and highs became basins. Such an inversion process had, naturally, a major effect on the distribution of Triassic and Jurassic rocks. The most complete successions are to be found in deeply submerged blocks, but these represent only remnants of deposits once laid down in a large sedimentary depression at the margin of the Fennoscandian Shield (Norling & Bergström 1987; Guy-Ohlson & Norling 1988, 1993; Norling & Wikman 1990).

Jurassic volcanism

As in the North Sea graben system, areas within the Scanian part of the Tornquist Zone were subjected to volcanism from the Middle Jurassic and onwards (Figs. 6, 33, 34). In Central Scania, which is dominated by gneiss and a patchy thin Jurassic sedimentary cover, at least 70 Mesozoic basaltic necks have been recorded (Bergström 1981). Most of their K-Ar datings group around 108 Ma and 167 Ma (Klingspor 1976). Palynological datings of tuffites related to the older group of basalt necks, the Middle Jurassic ones, imply Aalenian–Bajocian ages (Tralau 1973). The basalts are typically vitrophyric with columnar structures and undersaturated with respect to silica (Leif Johansson, Geological Institute, Lund, 1992, pers. comm.). Locally, the volcanic intrusions have had a profound effect on the early diagenesis of Liassic arenites. The Liassic Höör Sandstone was subjected to Middle Jurassic hot brine flushing leading to extensive quartz induration of the sediments (Ahlberg & Goldstein unpublished data). Equivalent strata of NW and SW Scania show no signs of volcanic influences.

Sedimentology

The deposition of Jurassic sediments in Sweden was strongly influenced by tectonic activities within the Tornquist Zone. In the sedimentary record this is reflected by numerous provenance shifts, disconformities and evidence of transgressions and regressions (facies shifts). In addition, the climate was a major factor controlling weathering, erosion and deposition.

Late Triassic and Early Jurassic deposition

Late Triassic–Early Jurassic strata of Sweden are by far most complete in NW Scania (Kågeröd Formation, Höganäs Formation and Rya Formation). Hence, sedimentological interpretations of this interval are mainly based upon investigations from that area (Vossmerbäumer 1970; Ahlberg 1990; Pieńkowski 1991a, 1991b).

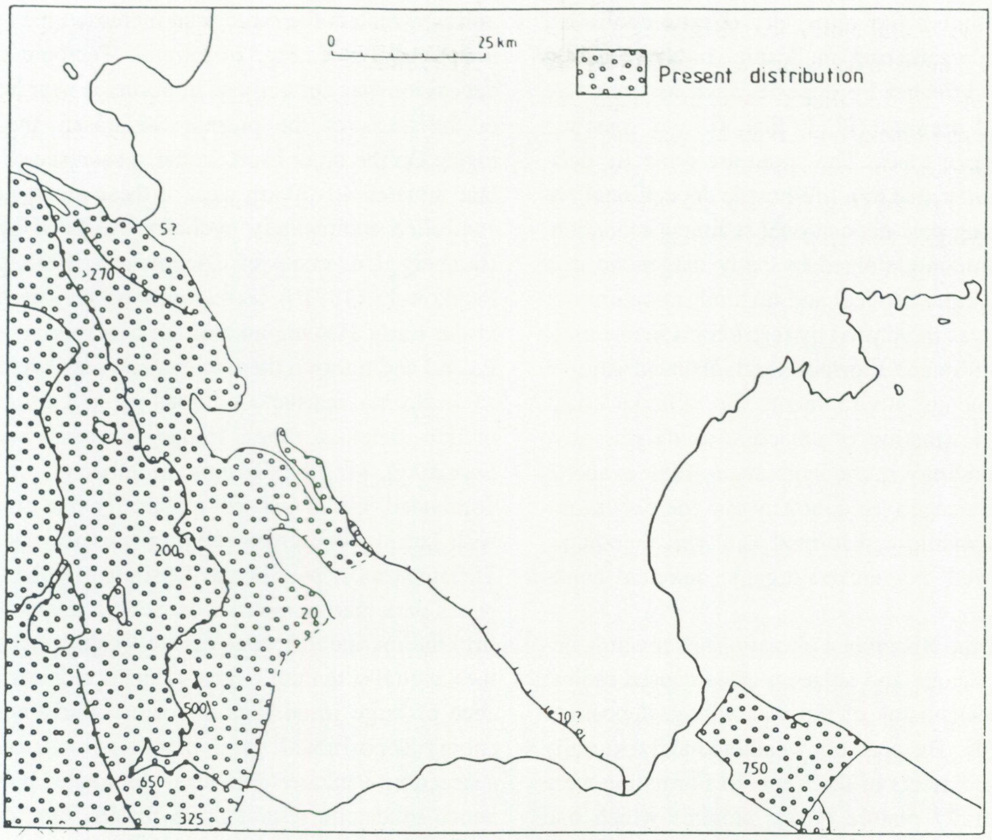


Fig. 6a. Present distribution of Pre-Rhaetian Triassic sediments (after Norling & Bergström 1987).

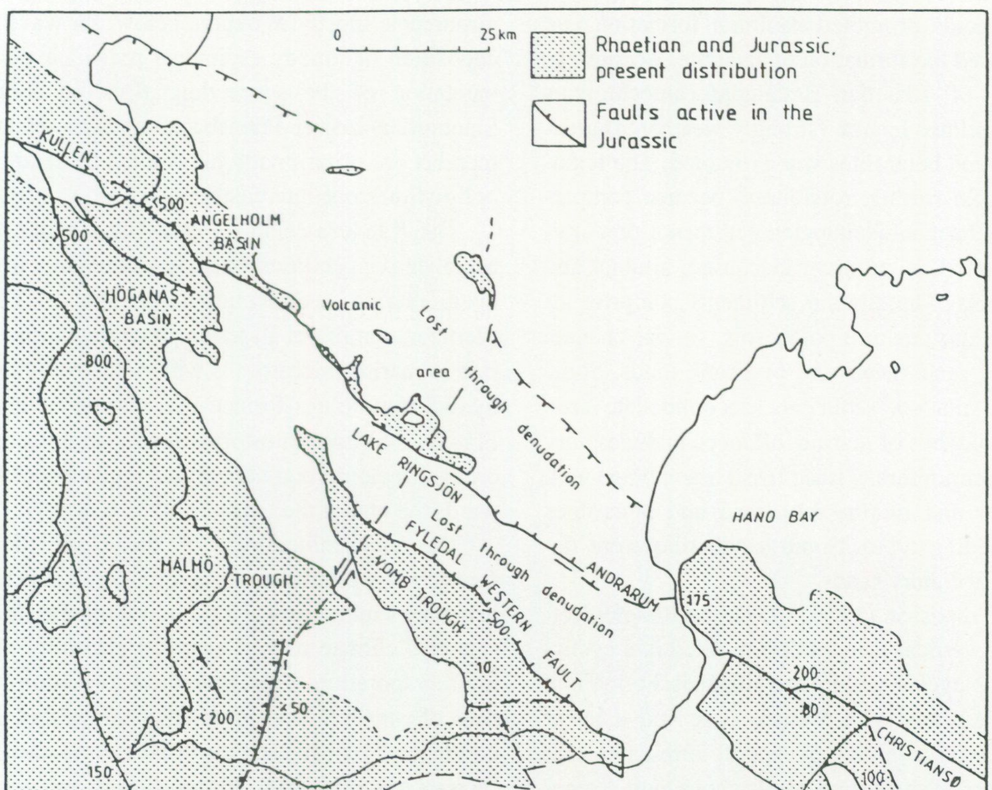


Fig. 6b. Present distribution of Rhaetian and Jurassic sedimentary rocks in Scania with surrounding areas together with synsedimentary faults. The volcanic activity ("volcanic area on the map") is dated as Jurassic to Cretaceous (after Norling & Bergström 1987).

In the Norian time a prevailing dry climate controlled sedimentation and weathering in Scania. In the Kågeröd Formation this is reflected by deposits such as immature conglomerates and arenites (Pl. I, Fig. a), and smectitic mudstones and wackestones. The strata are typically deficient in organic matter due to a life-hostile depositional environment and strong post-depositional sediment oxidation. They are also commonly stained by early diagenetic iron oxide (haematite). The chemical and textural immaturity of the detrital grains was monitored by restrictions in chemical weathering and sediment transportation characteristic of dry climatic continental environments (i.e. alluvial cones and playa lakes). Formation of smectitic muds was governed by raised alkalinity in the soils due to high evaporation and limited drainage (see comments on the clay mineralogy below). Haematite was formed as a typical eodiagenetic product of well oxygenized organic deficient continental strata.

At the onset of the Rhaetian a climatic shift towards humid conditions in Scania and adjacent areas caused radical changes in the mechanisms of the weathering, deposition and early diagenesis. The sparsely weathered and texturally immature clastic sediments of the Kågeröd Formation were followed by texturally mature quartz arenites which had been subjected to a dramatic increase in chemical weathering as CO_2-rich acid waters flushed the soils (see comments on clay mineralogy below). By the same token, leaching organic acids promoted kaolinite formation and completely supressed the formation of smectite. Accordingly, accumulation of Rhaetian–Hettangian autochtonous coal, kaolinitic argillites, mature (strongly weathered) arenites (Pl. I, Fig. b) and heterolites was promoted. The textural maturity (particle sorting, roundness) became comparably high as the Rhaetian–Hettangian sediments predominantly were deposited in turbulent lacustrine, alluvial and deltaic environments. The alluvial sediments comprise allochtonous coal-seams, mature palaeosols, fluvial channel and crevasse splay sand sheets and overbank muds. Some of the lacustrine muddy sediments accommodate iron ooides. Discrete evidence of marine influence includes very rare arenaceous foraminifers, a trace fossil assemblage with mixed fresh water and marine ichnotaxa and heterolites with intertidal bedding types. Some sandbodies were deposited as delta distributary sands.

According to Troedsson (1950, 1951), the Rhaeto–Hettangian lateral and vertical facies shifts resulted in a cyclicity pattern with 12 cycles within the Höganäs Formation. Ideally, each cycle starts with a sharp base and a lower coarse-grained alluvial arenitic sequence. It terminates with an upper, partly brackish marine argillaceous unit, sometimes interbedded with coal-seams. According to Troedsson, the cyclicity was attributed to repeated subsidence pulses, which at the same time increased the relief (i.e. sediment supply; cf. Fig. 24 herein). Tectonic control of the deposition was certainly of importance near horst structures in the areas of the present Söderåsen and Romeleåsen highs. On the other hand, in the subsurface of western Sealand situated 40–50 km west of these areas, no tectonically controlled sedimentary cyclicity has been observed (Lars Hamberg, University of Copenhagen, 1991, pers. comm.). Pieńkowski (1991b) correlated isochronous transgressions in the Early Hettangian and the Sinemurian in Scania and Poland and referred them to eustatic sea-level changes.

In Scania, marine conditions prevailed throughout Sinemurian–Aalenian times. Hence, the basal part of the Rya Formation, viz. the Döshult Member (L. Sinemurian), is dominated by nearshore mature coarse-grained arenites with herringbone cross-bedding (possibly of tidal origin). The uppermost part of the Döshult Member mostly comprises dark marine mudstones. Several ammonite finds confirm the marine influence on the Döshult deposits, whereas the texturally mature coarse-grained arenites and the presence of large fossil logs indicate a fairly near-shore high energy depositional environment (Troedsson 1951). The succeeding Pankarp Member is dominated by dull homogeneous mudstone with marine fossils. One coal-seam, recorded from bore-holes, may indicate renewed proximity to the shore during deposition. In general, however, post-Sinemurian Liassic sedimentation followed in quiet marine environments mostly at depths below the wave base. Hence, deposition of muddy sediments prevailed during the sedimentation of the succeeding Katslösa Member (Upper Sinemurian–Lower Pliensbachian). The mudstones of this member are occasionally interrupted by sandy horizons and oolitic limestone intercalations.

The Katslösa Member was followed by the Rydebäck Member (Upper Pliensbachian–Aalenian). In this interval, open marine sedimentation continued. The Rydebäck Member comprises a series of arenites and wackestones rich in marine microfossils with notable contents of glaucony and iron oolites formed in a marine environment (Pl II: Figs. b, c). Minor intraformational conglomerates imply increased tectonic activity (and a regressional tendency) towards the end of the Lias.

The clay mineralogy of the Upper Triassic–Lower Jurassic of western Scania is a sensitive indicator of climatic changes in the depositional environment. In the Norian, a semiarid climate caused elevated alkalinity in soils due to high evaporation. This promoted formation and preservation of smectite-bearing mudstones within sequences of continental redbeds. In the Rhaetian–Hettangian humidity increased dramatically. Plants thrived and contributed with humic acids and carbon dioxide to the soils. By the same token the period of dominating evaporation had come to an end. Consequently, alkaline weathering conditions were replaced by acid conditions. This promoted kaolinite formation and preservation and inhibited smectite formation. Kaolinite was mixed with detrital illite and chlorite during deposition in alluvial sediments. As the Sinemurian transgression overstepped the alluvial areas of western Scania, sea water alkalinity again allowed formation and preservation of smectites. These are found in varying proportions within the Rya Formation together with illite, chlorite, kaolinite and glauconite. Marine Liassic strata show swift lateral and vertical changes in clay mineralogy. This implies that detrital input from land had a profound effect on the marine sedimentation.

Upper Triassic–Lower Jurassic arenites in NW Scania show sharp provenance shifts between coarse-grained, chemically immature first cycle sands and polycyclic fine-grained sands. The redbeds of the Kågeröd Formation invariably contain the more immature coarse-grained arenite type, whereas the coal-bearing fluvio-deltaic Höganäs Formation is strongly dominated by the fine-grained arenite type. Due to tectonic instability in the sediment source areas, sudden intercalations of coarse-grained sands occur within the Höganäs Formation (Norling & Bergström 1987; Svensson 1989). Arenites within the Helsingborg Member in NW Scania show a dominance of fine-grained polycyclic sands with lower chemical and textural maturity than the more coarse-grained intercalations. This implies separate original sediment sources for the two arenite types of the Helsingborg Member (Ahlberg 1990). The basal, transgressive part of the marine Rya Formation is dominated by mature coarse-grained arenites. Open marine conditions (long shore sediment transport) during the deposition of the remaining Rya Formation promoted mixing of sand grain populations. Intensive bioturbation, low-energy of depositional environments and authigenic mineral precipitation caused effective mixing of sand and mud which formed sedimentary wackes.

Middle and Late Jurassic deposition

During Bajocian–Bathonian times the marine influence decreased in Scania as a result of renewed faulting at the margin of the East European Platform (Fig. 5). The tectonic influence led to a general regression over vast areas and the development of sedimentary facies similar to the Rhaetian deposits. A narrow depositional area across Scania acted as a communicating link between the Norwegian–Danish Basin and the Central European Basin (Fig. 5). To the west, the Ringköbing–Fyn High existed as a vast denudation area (Fig. 3). The depositional environments were dominated by continental (fluvial, lacustrine) and marginal (lagoonal, tidal) settings in Scania, the Norwegian–Danish Basin, and in the Central Graben. Marine conditions were shallow and limited to the Central European Basin (Jubitz *et al.* 1988). In Callovian time the sedimentation in Scania was again influenced by marine conditions which persisted during much of the Late Jurassic epoch (Figs. 10, 11). This led to the deposition of extensive offshore marine clays and silts.

The Bajocian deposits in Scania, the Fuglunda Member of the Mariedal formation (informal unit), and the Vilhelmsfält Formation are dominated by sandstone, claystone and coal arranged in cycles deposited in a transitional continental–marine setting during warm and humid conditions. The deposits contain numerous plant remains of ferns, cycadophytes, ginkgophytes and conifers, as well as rootlet beds linked to the coal-seams. The sandstone occasionally contains *Diplocraterion* burrows. The general succession of strata in one of the cycles of the Fuglunda Member is as follows: a) wavy thin rhythmically bedded heterolites deposited in interdistributary bays, b) horizontally laminated fine-grained sandstone with *Diplocraterion* deposited on the seaward side of a delta, c) horisontally laminated siltstone and very fine-grained sandstone with rootlets deposited on top of a delta lobe in a lower delta plain environment, d) coal formed on top of a delta lobe. Continuous subsidence in the depositional areas led to a repeated succession of strata. Thirteen cycles have been identified in the Fuglunda Member.

The succeeding Bathonian Glass Sand of the Mariedal formation is probably deposited as a transgressive prograding delta over tidally influenced lower delta plain deposits. A transgressive pulse is represented by calcareous marine deposits, e.g. the Fortuna Marl (Figs. 10, 11), in other parts of Scania (Helsingborg–Landskrona area), which is a member ranging from top Bathonian into the Lower Oxfordian (Norling 1970, 1972, 1981; Guy-Ohlson & Norling 1988).

In Late Jurassic times an increasing influence of marine conditions led to the formation of shallow marine clays and silt over vast areas in the Central European Basin, as well as in the Norwegian–Danish Basin. The area linking together the two basins, that is a narrow pathway between the Fennoscandian Shield and the Ringköbing–Fyn High was, however, still influenced by brackish conditions during most of the Late Jurassic (Figs. 5, 11).

At Eriksdal in the Fyledalen Valley, there is a major stratigraphical hiatus between the Bathonian Glass Sand and the Oxfordian–Kimmeridgian Fyledal Clay. In NW Scania, however, a more complete Upper Jurassic sequence has been recorded from bore-holes. The Fyledal Clay consists of a sequence of variably coloured clay- and siltstones. The uniform composition of this member within its distributional area, indicates an extensive low relief and quiet water depositional environment over Scania (Guy-Ohlson & Norling 1988). There is no evidence, however, that the sedimentation was synchronous all over the area (Norling 1981). The occurrence of rootlet beds, freshwater-brackish-marine fossils (ostracodes, arenaceous foraminifers, calcareous algae, calcareous foraminifers), caliche nodules, gypsum and organic rich beds with rootlets, verify deposition in shallow lakes, lagoons and swamps within a low relief coastal environment, i.e. coastal plain with periods of restricted shallow marine conditions (Erlström *et al.* 1991, 1993).

Tithonian deposits (Nytorp Sand in part, and the Vitabäck Clays, Fig. 11) are mainly formed in slightly more varied marginal depositional environments than the Fyledal Clay. The lithology of the Nytorp Sand indicates a prograding barrier-strand plain-delta system. The Jurassic–Cretaceous transitional beds (Vitabäck Clays) are again dominated by brackish to freshwater strata with some marine influence. These deposits are composed of partly cycle-bedded sequences starting with basal clays deposited in quiet waters (coastal lakes) and lagoons, which is evident from the composition of the molluscan fauna. Lacustrine conditions have been verified by palynomorphs (e.g. *Botryococcus*). The bedding sequence continues with sandy and silty deposits succeeded by clays with thin coal-seams and rootlets completing the infill sequence. Occurrence of iron-rich interbeds, enrichment of trace elements and an increased amount of mixed-layer clays (illite-smectite), indicate that pedogenic processes prevailed temporarily (cf. Erlström *et al.* 1991).

Diagenesis

Within the Tornquist Zone, Kimmerian (Late Triassic to Early Cretaceous) fault bounded basins were subjected to Subhercynian (Late Cretaceous) inversion tectonics (Norling & Bergström 1987). In this NW–SE oriented block-and graben area, vertical fault amplitudes of 2 km are recorded (Norling & Bergström 1987). Most Scanian Jurassic deposits were affected by these movements and are today found at various depths down to c. 2,000 m. Jurassic strata are typically low in organic maturity. Thermal Alteration Index (TAI) for the microflora averages around 3 (Dorothy Guy-Ohlson 1991, pers. comm.), whereas vitrinite reflectance data (Rm) commonly scatter around 0.4–0.5 % (Ahlberg *et al.* unpublished data). This implies that the majority of the Jurassic sediments rarely experienced temperatures higher than 70°–95° C.

Few diagenetic studies have been carried out in Jurassic deposits of Sweden. In the Hettangian of NW Scania, a low-temperature paragenetic sequence has been reconstructed, comprising early meteoric (fresh water) flushing followed by burial carbonate cementation in the methanogenic zone of the sedimentary column. Subsequent carbonate vein fillings were probably associated with Late Kimmerian inversion tectonics (Ahlberg, 1990). Most likely the "block-and-graben" tectonics with inversion movements have promoted repeated events of fresh water (meteoric) flushing of Jurassic permeable sediments.

As an exception to the normal low-temperature history of most Swedish Jurassic strata, the Rhaeto-Liassic Höör Sandstone of Central Scania has been intensely quartz indurated due to repeated hot brine flushing (Ahlberg & Goldstein, unpublished data). These events were probably caused by Middle Jurassic and later volcanic heat flows.

Lithostratigraphy

Due to lateral variation in facies and stratigraphical representation, Scania has been subdivided into different geographical areas for the regional stratigraphical presentation, viz. into NW Scania, SW Scania, Central Scania, the Vomb Trough, the Fyledalen Valley and the Hanö Bay. The subdivision into different areas is illustrated by Fig. 7.

NW Scania

Upper Triassic and Lower Jurassic

Kågeröd Formation. – The Norian is represented by arkosic sandstones and variegated clays and conglomerates regarded as continental redbeds which are distributed along the Tornquist Zone of Scania and Bornholm (Fig. 2). Their distribution in Scania is given in Figs. 1 and 6a. The Kågeröd Formation has a maximum thickness of about 272 m (Klappe well, NW Scania) according to Norling & Wikman (1990). In the present guide, one locality; Bälteberga gorge (p. 32), has been chosen to illustrate the Kågeröd Formation.

Höganäs Formation (Rhaetian–Hettangian). – This formation is subdivided into three members, two belonging to the Upper Triassic (Vallåkra and Bjuv Members) and one to the Lower Jurassic (Helsingborg Member). The whole for-

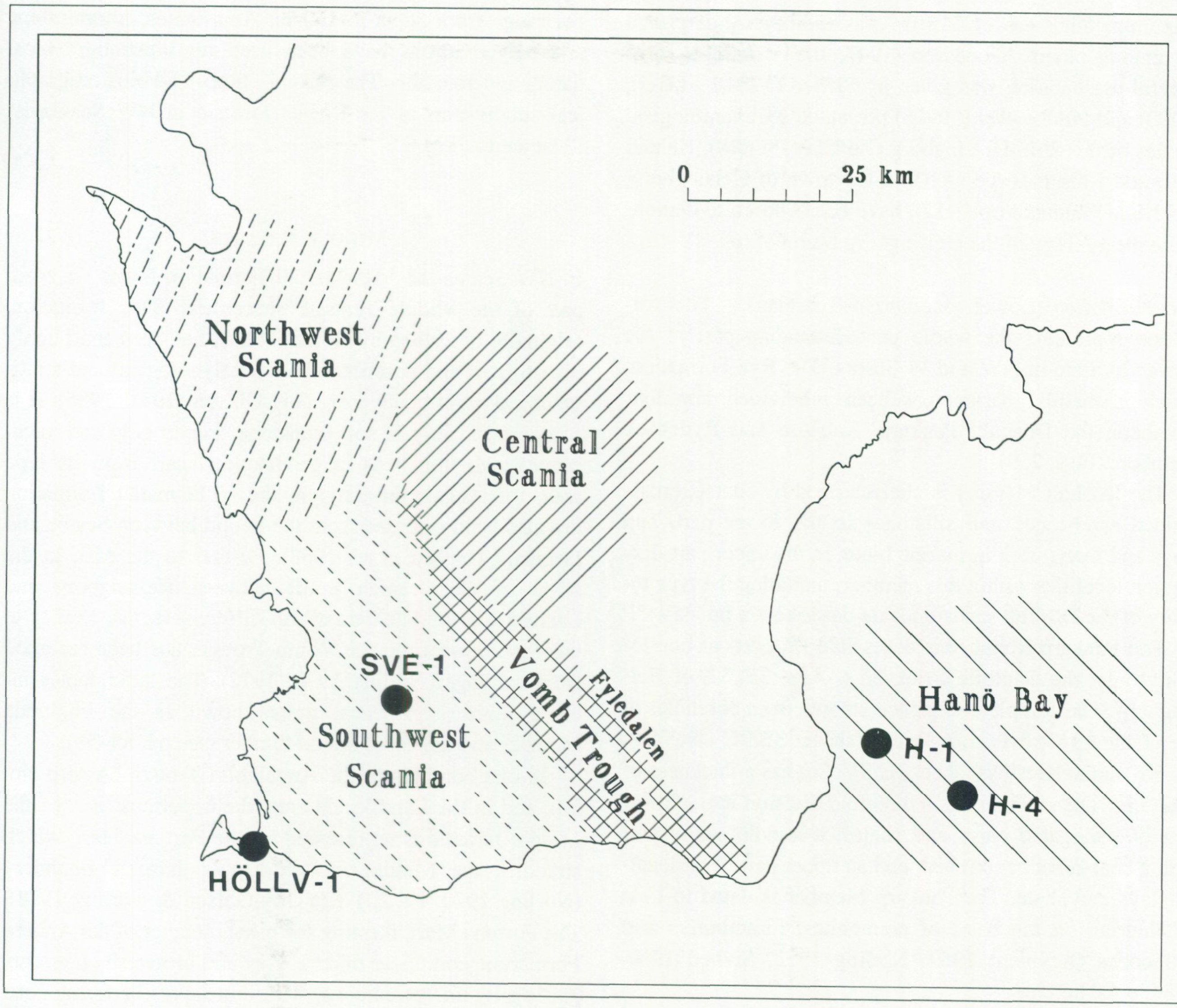


Fig. 7. Sketch map of Scania showing geographical areas referred to in the text: H-1 = Hanö Bay-1; H-4 = Hanö Bay-4; Höllv.-1 = Höllviken-1; SVE-1 = Svedala-1.

mation may have a maximum thickness of about 250 m (Figs. 2, 9, 22).

The basal member of the Höganäs Formation, the Vallåkra Member, is regarded as forming a transition between the continental Kågeröd Formation and the deltaic, coal-bearing deposits of the Bjuv Member (Sivhed 1984). The Vallåkra Member includes grey and variegated clays with sphaerosiderite and greenish sandstone lenses. In NW Scania, that is in the Höganäs–Söderåsen–Helsingborg area (Figs. 1, 4), this member shows a lateral variation in facies. Generally speaking, there is an easterly arenaceous facies and a westerly more argillaceous one. The Vallåkra clays have been used for making facade bricks, drainpipes etc. In this guide, locality A3 (p. 34), the northern quarry at Vallåkra, has been chosen to illustrate the characteristic geology of the unit.

The Bjuv Member, locally called "the mining beds" (in Swedish: "gruvlagren"), may be defined as the sedimentary sequence between and including the two main coal-seams of the Rhaetian. The lower seam (B-seam) forms the boundary to the Vallåkra Member. The upper seam (A-seam) has been chosen to mark the boundary to the Helsingborg Member and thus the lithostratigraphical boundary between the Triassic and the Jurassic, that is the Rhaetian–Hettangian boundary. As seen in the chapter on industrial minerals (p. 29), the Rhaetian coal and fire-clays have been mined for centuries in NW Scania on a scale not only of local importance. In fact, this mining was of national economic interest for more than 200 years. The Bjuv Member is represented by two localities in the present guide, viz. the N. Albert and Lunnom quarries (A5, A6, pp. 38, 39).

The Helsingborg Member (Hettangian) with a known maximum thickness of 215 m, was thoroughly described by, among others, Troedsson (1947, 1951). A more brief general presentation was given by Sivhed (1984). Ahlberg (1990) and Pienkowski (1991b) presented sedimentological studies of this unit. Helsingborg Old Clay Pit (A8), Halalid (A9) and Hälsan gorge (A10) in the town of Helsingborg, and Kulla Gunnarstorp (A12), have been chosen to demonstrate the geology of the Helsingborg Member (pp. 42–45).

Rya Formation (Lower Sinemurian–Toarcian). – This formation represents the whole post-Hettangian part of the Lower Jurassic in NW and W Scania. The Rya Formation, which is mainly marine, has been subdivided into four members; the Döshult, Pankarp, Katslösa and Rydebäck Members (Figs. 2, 9).

The Döshult Member is characterized by coarse, cross-bedded sandstones and siltstones in the lower part, and clays and marls, rich in marine biota, in the upper part. Excursion localities within this member, including the type locality of the Döshult sandstone, are described in pp. 45–47.

The Pankarp Member is accessible (in part) at one locality only, the Gantofta Brick Pit (A4, p. 35) SE of Helsingborg. The complete sequence, known from boreholes in the Pankarp–Strövelstorp area (sheet 3B/3C NO/NV, 5c–5d) and at Katslösa (sheet 3C SV, 2c) has a thickness of 60–75 m. The member has a threefold division into a lower part of variegated clays and shales, a middle sandy part with a coal-seam or root bed, and an upper part of variegated clays and shale. The Pankarp Member is dated to Late Sinemurian on the basis of ammonites, foraminifers and ostracodes (Reyment 1969; Norling 1972; Sivhed 1980, 1984, p. 20 herein).

The Katslösa Member consists mainly of greenish, brownish and dark grey claystones, siltstones and sandstones with a varying content of iron. Thin beds of limestones and iron oolites do also occur. Observed maximum thicknesses range from 30 m to 40 m. The sediments were deposited in marine environments and have yielded fairly rich macro- and microfaunas indicating a Late Sinemurian to Early Pliensbachian age (p. 20). The Katslösa deposits were temporarily exposed in a ditch system described by Troedsson (1951) some 10 km SE of Helsingborg centre. The member and its microfaunas are well known from many boreholes in NW and W Scania (Norling 1972; Sivhed 1980).

The Rydebäck Member (Upper Pliensbachian – Aalenian) includes sandy and silty, partly oolitic sediments with a varying content of clay and calcium carbonate. Intervals of variegated rocks occur, mainly with reddish, greenish and red-spotted blackish colours. Several conglomeratic horizons occur in the upper part of the sequence, indicating breaks in the marine succession. Thicknesses of this member range from 50 m to 100 m. Ammonites, foraminifers, and palynomorphs have been used for biostratigraphical dating and zonation. The chrono-, litho- and biostratigraphical subdivision of the Lower Jurassic in NW Scania is illustrated in Fig. 9.

Middle Jurassic

In NW Scania the Vilhelmsfält Formation forms the main part of the Middle Jurassic succession. This formation, originally described by Bölau (1959), has been thoroughly investigated and described from a palynological and stratigraphical point of view by Guy-Ohlson (1971, 1986). It is composed mainly of soft mudstone, in part silty and micaceous, with thin beds of sandstone. Apart from its type area, the Ängelholm Trough, the Vilhelmsfält Formation has also been recorded from the Sound between Scania and Denmark (Larsen *et al.* 1968). Further to the east, in the slope of the Scanian uplift between Helsingborg and Landskrona, Middle Jurassic in different facies, similar to what is known from the Vomb Trough, has been recorded from drillings (Norling 1970, 1972). The latter facies include lithostratigraphical units known as the Fuglunda Member and the Glass Sand Member (see pp. 55–58).

In one borehole in the Ängelholm Trough (Åstorp No. 20), and in the Landskrona area, the uppermost part of the Middle Jurassic is represented by the Fortuna Marl, which straddles the Middle Jurassic–Upper Jurassic boundary (Norling 1970, 1972, 1981; Guy-Ohlson & Norling 1988). The Fortuna Marl, forming the basal member of the Annero Formation, comprises of dark-grey and brownish claystone, partly silty and calcareous, with thin layers of ferruginous claystone and silty limestone. The distribution in Scania of Middle Jurassic/Upper Jurassic strata in marine facies has been treated by Norling (1981).

Upper Jurassic

The above described Fortuna Marl (top Bathonian–Lower Oxfordian) thus forms a transitional unit to the Upper Jurassic. Along with this member, the Fyledal Clay, Nytorp Sand and Vitabäck Clays represent the Annero Formation, which is characteristic of NW Scania as well as of the Vomb Trough. The Annero Formation of NW Scania has been described by Norling (1972, 1981) and Guy-Ohlson & Norling (1988). The Fyledal Clay, Nytorp Sand, and Vitabäck Clays have a fairly wide distribution in Scania even outside the northwestern part of the province. The presentation of the Upper Jurassic lithostratigraphy of the Vomb Trough (p. 54) is also valid for NW Scania.

SW Scania

SW Scania comprises the area southwest of the Romeleåsen Horst western faultline, i.e. the western boundary of the Tornquist Zone. This part of Scania belongs to the Danish Subbasin. Within the area several tectonic blocks contain a thick Mesozoic–Cenozoic cover with a somewhat varying stratigraphical representation, due to individual vertical block movements.

In SW Scania, Upper Triassic–Jurassic strata beneath the Quaternary cover form the rock surface along a very narrow zone SW of the Romeleåsen Horst only (Figs. 1, 17). Further towards the southwest condensed Upper Triassic–Jurassic deposits with numerous hiata are to be found at depths between 1,000 m and 2,000 m (Guy-Ohlson, pers. comm. 1992). Current investigations concern drill cores from Svedala-1 and Höllviken-2 wells (Fig. 7) and relevant geophysical data (Ahlberg *et al.*, unpublished data). In Svedala-1, a strongly condensed sequence (c. 80 m thick) of coarse-grained Norian alluvial cone redbeds and fine-grained Middle Rhaetian coal-bearing palaeosols are directly overlain by Lower Cretaceous marine wackestones. Thus, all Jurassic deposits on this tectonic block were eroded prior to the end of the Early Cretaceous. The Höllviken-2 well, located to a deeper, more distal part of the basin, on the other hand, penetrated a considerably thicker Upper Triassic–Jurassic sequence. In this borehole, a thick sequence of Norian redbeds rests on older Triassic strata and is succeeded by a condensed Rhaetian-Kimmeridgian interval. The Norian redbeds of Höllviken-2 comprise numerous caliche horizons. The Rhaeto–Jurassic core sequences of Höllviken-2 show lithologies comparable to stratigraphically corresponding ones of NW Scania. Hence, from a sedimentological and diagenetical point of view Upper Triassic–Jurassic strata of SW Scania and NW Scania have much in common.

Central Scania

In Central Scania, Lower Jurassic strata (and perhaps also Rhaetian) rest as erosional remnants directly upon the weathered crystalline basement. The Lower Jurassic (Hettangian) rocks are referred to as the Höör Sandstone (Fig. 8). This unit is succeeded by tuffites and sedimentary rocks not given any lithostratigraphical unit name. Parts of the Höör Sandstone are strongly quartz cemented. Different sandstone types within this formation were first defined by Hermelin (1804).

Wikman & Sivhed (1993) made a threefold division of the Höör Sandstone. The basal part, 1 m to 15 m in thickness, is represented by mudstones and siltstones without any unit name (Fig. 8).

The middle unit of the Höör Sandstone is called the

Chronostratigraphy		Formation	Member
JURASSIC	Sinemurian	HÖÖR SANDSTONE	VITTSERÖD
	Hettangian		STANSTORP
TRIAS-SIC	Rhaetian		UNNAMED

Fig. 8. Rhaetic–Liassic stratigraphy of Central Scania.

Stanstorp Member (local term: kvarnstenen = the millstone). This unit is made up of coarse, quartz-cemented arkosic strata occasionally intercalated by mudstones. The Stanstorp Member, in the past used for millstone production, has a maximum thickness of some 15 m. According to Antevs (1919), Nathorst (1910) and Troedsson (1940), this sequence may be lithostratigraphically correlated with a certain interval of the Helsingborg Member, Höganäs Formation.

The upper unit of the Höör Sandstone Formation is named the Vittseröd Member. This unit comprises fine-grained, quartz cemented sandstone with a total thickness of c. 25 m.

South of Lake Finjasjön, in the northern part of Central Scania (Figs. 1, 7), a sequence of bituminous shales, sandstones, mudstones and conglomerates occurs, which has been dated to the Sinemurian–Pliensbachian (Nilsson 1958; Lund 1977). This sequence, about 70 m in thickness, is known from boreholes only.

Tuffitic sediments with volcanic bombs and wooden fragments, dated to the Toarcian-Aalenian on their sporomorph contents by Tralau (1973), are found at different localities in Central Scania. Djupadalsmölla (p. 50, Fig. 31) is an example of such a locality. Here, the tuffites rest directly on deeply kaolinized crystalline rocks. Close to Koholma there is another similar locality (p. 52).

The Vomb Trough and the Fyledalen Valley

The Jurassic lithostratigraphy of this area is comprehensively treated in the description of the geology of Eriksdal (p. 54).

The Hanö Bay

Upper Triassic and Jurassic strata occupy the deepest parts of the sedimentary sequence in the Hanö Bay (Fig. 7). Their presence has been verified in two wells drilled in 1973 for hydrocarbon exploration by OPAB (Swedish Oil Prospecting Company). In the southwest, the Phanerozoic deposits of the Hanö Bay are bounded by the Linderödsåsen–Christiansö Horst (Fig. 4), whereas their northern boundary is erosional (Norling & Skoglund 1977; Kumpas 1980). In Hanö Bay H-1 well (Fig. 7), > 72 m of Triassic deposits were penetrated. The uppermost 42 m of this sequence include calcareous, glauconitic clay- and siltstones, which have yielded foraminifers originally described from the Rhaetian of Austria (Kristan-Tollmann 1957, 1964; Norling & Skoglund 1977). A meagre ostracode fauna indicates a Late Triassic age too. The Rhaetian deposits of the Hanö Bay, which are resting on nonfossiliferous, clayish, partly variegated sandstones of Triassic style, differ from the coal-bearing clayish and silty deposits characteristic of mainland Scania, not least because of their partly marine character. No lithostratigraphical correlation has been possible. The Triassic sequence of the Hanö Bay rests directly upon the crystalline basement.

In the H-1 well the Lower Jurassic is represented by 41 m of greyish green clay and claystone and greyish, glauconitic, pyrite-bearing sandstone layers interbedded (Norling 1973; Tallbacka 1974; unpublished reports). A succeeding sequence, 63 m in thickness has been assigned to the Middle Jurassic-Upper Jurassic, partly on lithostratigraphical grounds (8 m of coal-bearing deposits reminding of Middle Jurassic strata elsewhere in Scania), partly based on micropalaeontlogy (Callovian foraminifers and Kimmeridgian ostracodes).

In the Hanö Bay H-4 well, further more distant from the eastern Scanian coast and closer to the Christiansö Horst faultline (Fig. 4), the Rhaetian to Middle Jurassic is rudimentary, whereas the Upper Jurassic is thicker than in the H-1 well. From biostratigraphical evidence it seems as if a Late Jurassic pure marine episode has lasted longer in this area than in any other parts of Scania. The lithostratigraphical equivalent to the Fortuna Marl, spanning the Middle Jurassic/Upper Jurassic boundary, is not succeeded by the Fyledal Clay as in mainland Scania, but by a series of truly marine, glauconitic and calcareous siltstones and mudstones (Norling 1973, 1981; Norling & Skoglund 1977; Kumpas 1980).

Biostratigraphy

The stratification of the Swedish Jurassic is summarized in three tables, one for each of the Jurassic Series (Figs. 9, 10, 11). These tables inform about chronostratigraphy, lithostratigraphy, and biostratigraphy based on four fossil groups, viz. ammonites, foraminifers, ostracodes and palynomorphs. The stratigraphical ranges in Swedish Rhaetian –Jurassic strata of selected foraminifers and palynomorphs are given in Figs. 12, 13, 14.

Ammonites

In the Jurassic of Sweden, ammonites are conspicuous by their absence with the exception of their presence in a few Lower Jurassic zones ranging from the Lower Sinemurian into the basal Toarcian (Fig. 9). The ammonite fauna of the Jurassic in Sweden has been treated by Lundgren (1881), Troedsson (1951), Hoffman in Bölau (1959), and Reyment (1959, 1969).

As to the Sinemurian, the following zones are indicated by ammonite finds in outcrop sections and core material:

Oxynoticeras oxynotum
Asteroceras obtusum
Caenisites turneri
Arnioceras semicostatum
Arietites bucklandi

The presence of only four zones is indicated in Pliensbachian strata, viz. :

Pleuroceras spinatum
Amalthaeus margaritatus
Prodactylioceras davoei
Uptonia jamesoni

whereas only one Toarcian ammonite zone has been recorded: the Zone with *Dactylioceras tenuicostatum*.

Further information about ammonite records and the occurrence of other fossils is given in the descriptions to the guide localities (see also Fig. 9).

Foraminifers

Foraminifers play an important role in the Jurassic biostratigraphy of Sweden.

As to the Lower Jurassic (Fig. 9), four biozones based on foraminifers have been established, ranging from the top Hettangian throughout the series (Norling 1972; Guy-Ohlson & Norling 1993).

Astacolus semireticulata Zone corresponds to the uppermost part of the Helsingborg Member (Hettangian) and the Döshult Member (L. Sinemurian). Within this zone, the *Reinholdella margarita & Neobulimina* sp. No. 2 Subzone corresponds to the marl and limestone facies of the Döshult Member. The sandy part (Döshult sandstone) of this unit is devoid of foraminifers.

The *Marginulina spinata spinata* Zone is correlated with the Upper Sinemurian and Lower Pliensbachian and covers the major part of the Pankarp and Katslösa Members (Fig. 9). This zone has been divided into three subzones, viz. the *Citharina inaequistriata & Marginulina s. spinata* Subzone (U. Sinemurian), the *Astacolus denticula carinata & Marginulina s. spinata* Subzone (L. Pliensbachian), and the *Brizalina liassica amalthaea* Subzone, the latter straddling the Lower/Upper Pliensbachian boundary.

Saracenaria sublaevis Zone covers the lower part of the Rydebäck Member (Upper Pliensbachian), whereas the *Citharina clathrata* Zone corresponds to the upper part of this member (Toarcian–Aalenian). Diagnostic foraminiferal species of the different zones recognized are listed in Appendix I, p. 64.

For the major part of the Middle Jurassic, foraminifers are not useful tools in biostratigraphy due to the predominating nonmarine conditions during this epoch. In thin intercalations resulting from marine ingressions in mainly nonmarine sequences, however, foraminifers have been found in core material, indicating a Bajocian age (Fig. 10; Zone with *Epistomina parastelligera & Reinholdella dreheri*).

No foraminifers useful in stratigraphy have been obtained from the outcropping Middle Jurassic sequence at Eriksdal (p. 54). Middle Jurassic strata in Fortuna Marl facies have yielded a fairly rich foraminiferal assemblage referred to the *Saracenaria oxfordiana & Saracenaria phaedra* Zone (Norling 1972). This zone has a range from the top Bathonian/Callovian into the Early Oxfordian (Figs. 10, 11).

The outcropping Upper Jurassic sequence in Sweden is poor in foraminifers. Based on records from core material, however, a subdivision into four zones (with a gap for the top Kimmeridgian-basal Tithonian Nytorp Sand) has been made, which indicates the same ages as do the palynomorph zones and diagnostic ostracode species (Fig. 11 herein, Norling 1972, 1981; Guy-Ohlson & Norling 1988, 1993; Bruun Christensen 1968; Sivhed in Erlström *et al.* 1992). Among these zones the *Reophax suprajurassica* Zone corresponds to the lower part of the Fyledal Clay Member (Oxfordian), whereas the *Valvulina meentzeni* Zone characterizes the upper part of the Fyledal Clay (Kimmeridgian).

For the succeeding member, the Nytorp Sand, there is no foraminiferal evidence. The same is true concerning palynomorphs. The uppermost foraminiferal zone of the Jurassic in Sweden, corresponding to the Vitabäck Clays of the Annero Formation, is called the *Lenticulina muendensis* Zone, the denominator being restricted to the top Jurassic elsewhere in Europe (Tithonian, Portlandian). Characteristic species of various foraminiferal assemblages corresponding to the different zones, are listed in Appendix I, p. 64. In Fig. 12 (p. 26) Fifty selected foraminiferal taxa are listed and their stratigraphical ranges in Sweden and Europe are given.

Ostracodes

The Lower Jurassic Series of Sweden is in part fairly rich in ostracodes. Sivhed (1980) made an ostracode zonation of the Sinemurian and the Lower Pliensbachian (Fig. 9). As to the Hettangian no ostracodes of stratigraphical significance have been found. A list of diagnostic ostracodes is presented in Appendix II (p. 65).

In Sivhed's (1980) zonation the *Cristacythere betzi – Cristacythere crassireticulata* Zone corresponds to the middle part of the Döshult Member (Rya Formation). The ostracode assemblage of this zone indicates an Early Sinemurian age. The zone can be correlated with the *Arietites bucklandi* and *Arnioceras semicostatum* ammonite zones.

The Upper Sinemurian-Lower Pliensbachian sequence, corresponding to the upper Döshult, Pankarp and Katslösa Members of the Rya Formation, is referred to the *Ogmoconchella danica* Zone by Sivhed. Within this zone, three ostracode subzones have been identified, viz. the *Progonoidea reticulata* Subzone (corresponding to the *Caenisites turneri* and *Asteroceras obtusum* ammonite zones), an interval subzone with insufficiently known ostracode fauna, corresponding to the *Oxynoticeras oxynotum* and *Echioceras raricostatum* ammonite zones, and the *Gramannella apostolescui – Kinkellinella (Klinglerella) foveolata* Subzone. The latter subzone seems to cover the major part of the Lower Pliensbachian sequence (Katslösa Member) and corresponds to the three ammonite zones *Uptonia jamesoni, Tragophylloceras ibex* and *Prodactylioceras davoei* (Fig. 9). As to the Upper Pliensbachian–Toarcian sequence of Sweden, the ostracode fauna has not yet been investigated.

The Middle Jurassic and Upper Jurassic Series of Sweden have not yet been given any ostracode zonations

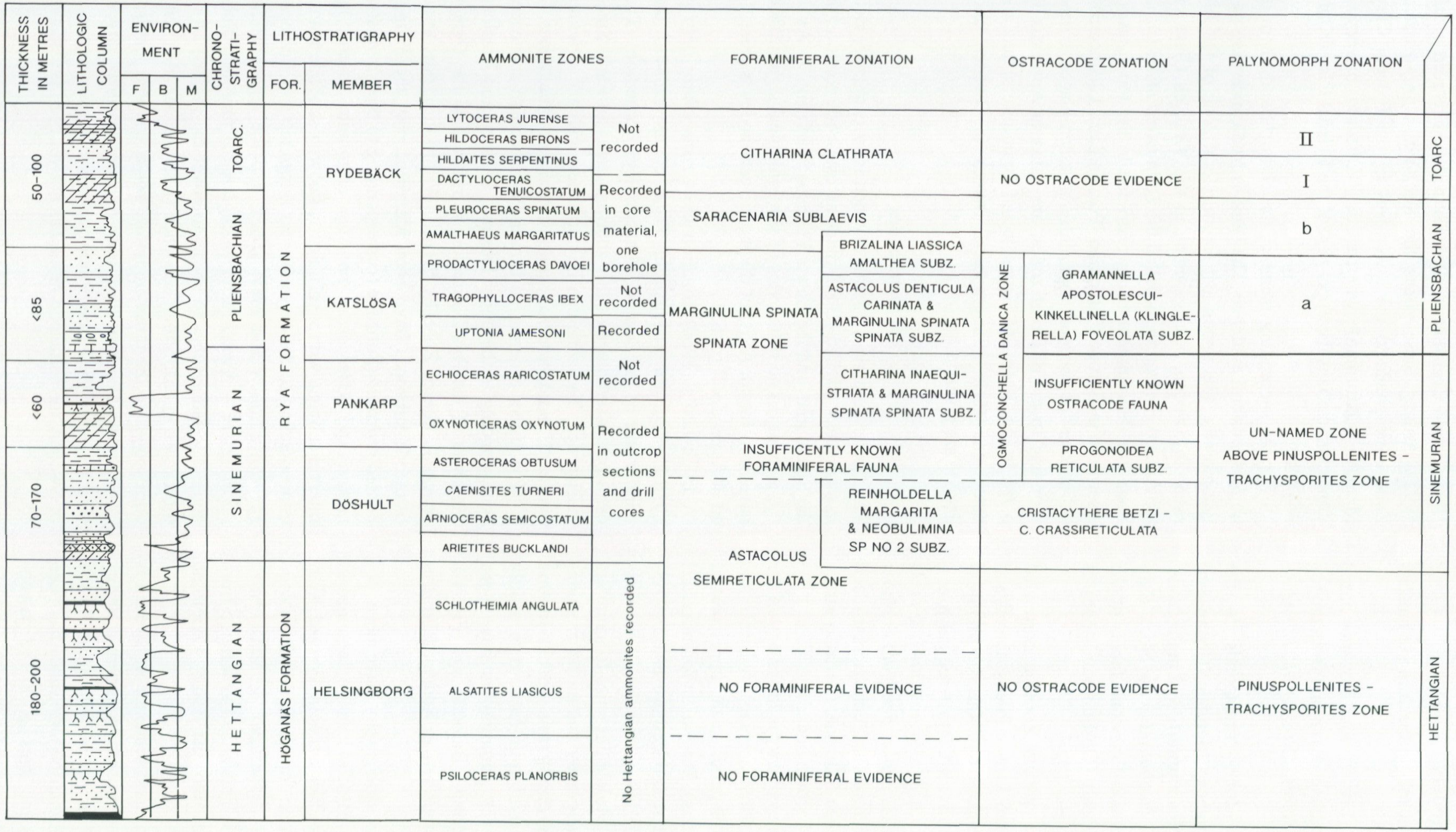


Fig. 9. Lower Jurassic chrono-, litho-, and biostratigraphy of Sweden. Based mainly on works by Lundgren 1881; Reyment 1959, 1969; Norling 1972; Guy-Ohlson 1981, 1986, 1989; Sivhed 1980, 1984.

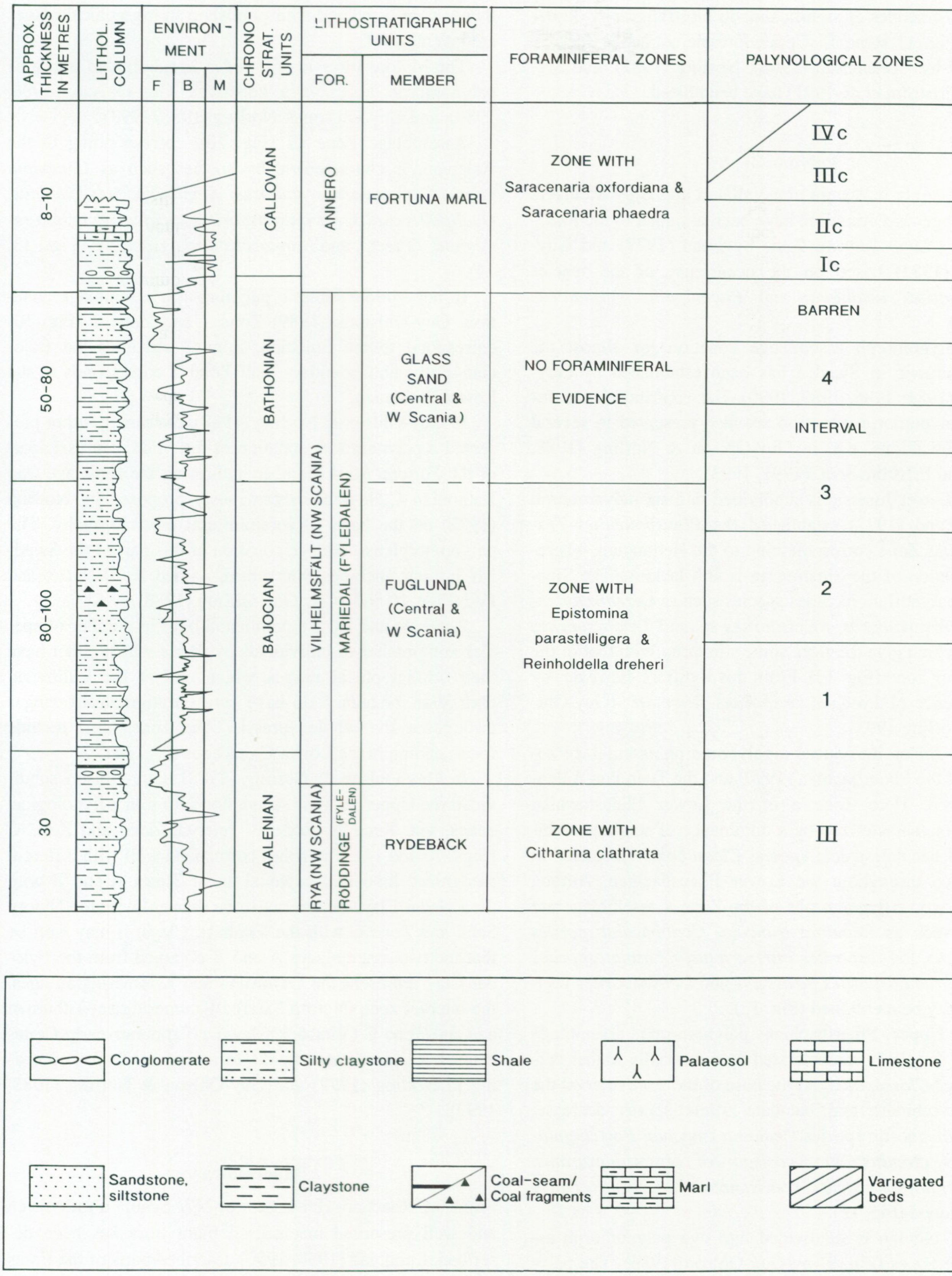


Fig. 10. Middle Jurassic chronostratigraphy, lithostratigraphy and biostratigraphy, including legend to Figs. 9, 10, 11. Based mainly on Norling 1972; Guy-Ohlson 1986, 1989; Sivhed 1984; Guy-Ohlson & Norling 1988, 1993.

though ostracodes of significance in biostratigraphy do occur. In Fig. 11 some 15 Upper Jurassic ostracode species, recorded by Christensen (1968), Norling (1981), and Sivhed (in Erlström *et al.* 1991) have been listed.

Palynomorphs

Rhaetian strata in Scania, the Vallåkra and Bjuv Members of the Höganäs Formation, have been assigned to the *Rhaetopollis – Limbosporites* Zone by Lund (1977) and Guy-Ohlson (1981) based on the occurrence of the species *Limbosporites lundbladii* and *Rhaetopollis germanicus* (Fig. 13).

A palynomorph assemblage zonation for almost the whole Jurassic in Sweden has been established by Guy-Ohlson (1981, 1986, 1989, 1990). Her contributions to Jurassic palynomorph zonation are also presented in several joint publications, e.g. in Guy-Ohlson & Norling (1988, 1993) and Erlström *et al.* (1991, 1993).

The Lower Jurassic is subdivided into six palynomorph zones. Lund (1977) established the *Pinuspollenites–Trachysporites* Zone correspondning to the Hettangian, whereas a zonation of the Sinemurian is still lacking. The Sinemurian palynoflora includes species such as *Cerebropollenites macroverrucosus, Riccisporites* sp. and *Trachysporites fuscus*, which give the flora some similarity with that of the underlying zone (Fig. 13). From this it differs, however, by the presence of *Lycopodiumsporites semimuris* (Guy-Ohlson & Norling 1993).

Guy-Ohlson introduced a palynomorph assemblage zonation of the Pliensbachian (1990) and the Toarcian–Aalenian (1986). Here Zone a of the Lower Pliensbachian (Fig. 9) is characterized by a dominance of scarbrate-echinate and baculate trilete spores. *Classopollis* fluctuates in abundance throughout the Lower Pliensbachian. Among characteristic palynomorphs of the Zone a assemblage are species such as *Cepulina truncata, Conobaculatisporites mesozoicus, Zebrasporites interscriptus, Chasmatosporites hians, Foraminisporites jurassicus* and *Ischyosporites variegatus* may be mentioned (Fig. 13).

The Upper Pliensbachian palynomorph assemblage (Zone b, Fig. 9) is characterized by a markedly higher percentage of *Classopollis*. At the base of the zone interval the scarbrate-echinate and baculate trilete spores decrease. Among diagnostic species *Cepulina truncata, Polycingulatisporites circulus, Verrucosisporites obscurilaesuratus, Nannoceratopsis gracilis*, and *Nannoceratopsis senex* may be mentioned (Fig. 13).

The Toarcian is subdivided into two palynomorph assemblage zones (Fig. 9) by Guy-Ohlson (1986). The palynomorph zonation of the Lower Jurassic and its correlation with faunal zonations, litho- and chronostratigraphical units is given in Fig. 9, p. 22. In Fig. 13 some 30 palynomorph taxa from the Rhaetian to the basal Middle Jurassic strata of Sweden are listed and their published stratigraphical ranges are given.

The Middle Jurassic of Sweden is subdivided into nine palynomorph assemblage zones by Guy-Ohlson (1986, 1989), and Guy-Ohlson & Norling (1988, 1993).

Assemblage Zone III (Fig. 10), corresponding to the Aalenian, is characterized by species such as *Campenia gigas, Ceratosporites spinosus, Staplinisporites caminus, Ovalipollis ovalis, Auritulinasporites triclavis, Entylissa reticulata, E. tecta*, and *Nannoceratopsis gracilis-2* (Figs. 13, 14).

In her Middle Jurassic palynomorph assemblage zonation, Guy-Ohlson's (1989) Zone 1 and Zone 2 (Fig. 10) correspond to the Bajocian, Zone 3 straddles the Bajocian–Bathonian boundary, and Zone 4 corresponds to the Lower Bathonian.

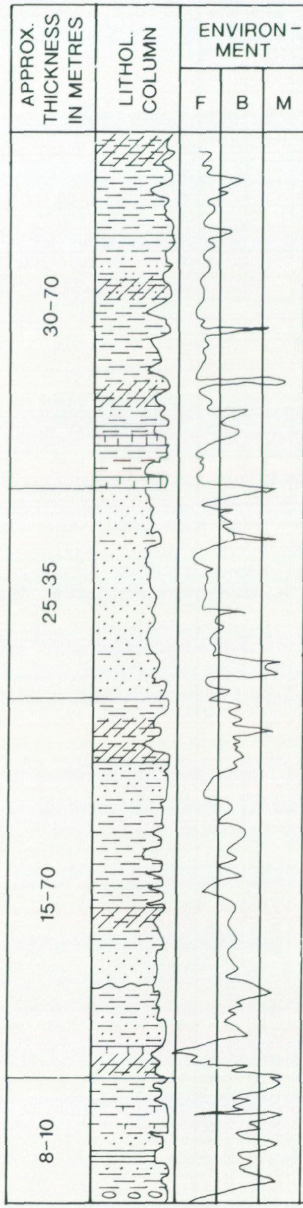
In Guy-Ohlson & Norling (1988), the senior author presented a palynomorph zonation of the Middle Jurassic part of the Fortuna Marl Member, indicating the same age (top Bathonian–Callovian) as previously proposed by Norling (1972) on the basis of foraminiferal biostratigraphy. The palynomorph assemblage zonation of this part of the Swedish Jurassic includes four zones, named Ic, IIc, IIIc, and IVc (Figs. 10 and 14 by Guy-Ohlson (1988).

Zones Ic and IIc are dominated both in number of species and number of individuals by forms which either have their stratigraphical ranges which end at the Callovian/Oxfordian boundary or have long stratigraphical ranges throughout the whole Jurassic. The zones also include forms ending in the Lower Cretaceous (Fig. 14).

In Guy-Ohlson & Norling (1988), Guy-Ohlson subdivided the Upper Jurassic succession into four palynological zones, viz. Zone A, Zone B, Interval Zone and Zone C (Figs. 10 and 14). The zones correspond well with different recognized lithostratigraphical units: Zones A and B with the Fyledal Clay, the interval zone (barren) with the Nytorp Sand and Zone C with the Vitabäck Clays. It may well be that the two assemblages A and B obtained from the Fyledal Clay represent the Oxfordian and Kimmeridgian ages, the interval zone (Nytorp Sand) a Kimmeridgian–Tithonian age and Zone C (Vitabäck Clays) a Tithonian–early Cretaceous age, as indicated by the foraminiferal faunas according to Norling (1972) and Guy-Ohlson & Norling (1988, 1993).

Macroflora

From the Rhaetian–Hettangian of NW Scania a rather rich and well preserved macrofossil plant flora has been described. Lundblad (1950, 1959) described parts of the floras and gave reviews of previous work. A Middle Jurassic macrofossil flora (and a dispersed microflora) was described by Tralau (1966, 1968).



APPROX. THICKNESS IN METRES	CHRONO-STRAT. UNITS	LITHOSTRATIGRAPHIC UNITS: FOR	LITHOSTRATIGRAPHIC UNITS: MEMBER	FORAMINIFERAL ZONATION	PALYNOLOGICAL ZONATION	SELECTED DIAGNOSTIC OSTRACODES
30–70	BERR. – TITHONIAN	ANNERO FORMATION	VITABÄCK CLAYS	Lenticulina muendensis ZONE	C	Cypridea valdensis praecursor Fabanella mediopunctata Fabanella ornata Klieana calyptroides Macrodentina retirugata Macrodentina transiens Mantellina purbeckensis Scabriculocypris trapetzoides
25–35	TITHONIAN – KIMMERIDGIAN	ANNERO FORMATION	NYTORP SAND	NO FORAMINIFERAL EVIDENCE	INTERVAL ZONE	
15–70	KIMMERIDGIAN – OXFORDIAN	ANNERO FORMATION	FYLEDAL CLAY	Valvulina meentzeni ZONE	B	Cytheropteron decoratum Damonella pygmaea Klieana alata Klieana calyptroides Macrodentina rudis Rhinocypris jurassica Rhinocypris rasilis
				Reophax suprajurassica ZONE	A	
8–10	OXFORDIAN		FORTUNA MARL	Saracenaria oxfordiana & S phaedra ZONE	Oxfordian part of the Fortuna Marl not investigated	

Fig. 11. Upper Jurassic chrono-, litho- and biostratigraphy of Sweden. Based mainly on Norling 1972; Christensen 1968; Christensen & Kilenyi 1970; Guy-Ohlson & Norling 1988, 1993 and Erlström *et al.* 1991, 1993.

SELECTED JURASSIC FORAMINIFERA
AND
THEIR STRATIGRAPHICAL RANGES
IN SWEDEN AND EUROPE

ERIK NORLING 1991

	UJ			MJ			LJ					UJ				MJ				LJ				
	Vitabäck Clays	Nytorp Sand	Fyledal Clay	Fortuna Marl	Glass Sand	Fuglunda Member	Rydebäck Member	Katslösa Member	Pankarp Member	Döshult Member	Helsingborg Member	Basal Cretaceous	Tithonian	Kimmeridgian	Oxfordian	Callovian	Bathonian	Bajocian	Aalenian	Toarcian	Pliensbachian	Sinemurian	Hettangian	Rhaetian
1. *Lenticulina muendensis* Martin	■												●											
2. *Pseudoctyclammina* sp.			■										●	●										
3. *Valvulina meentzeni* Klingler			■											●										
4. *Reophax helvetica* Haeusler			■											●						●				●
5. *Sorosphaera scanica* Norling			■											●										
6. *Eoguttulina pisiformis* Gordon			■												●									
7. *Lenticulina fraasi* (Schwager)			■	■											●	●								
8. *Astacolus gordoni* Norling			■												●									
9. *Reophax suprajurassica* Haeusler			■												●									
10. *Haplophragmoides canui* Cushman			■							■						●	●							
11. *Saracenaria cornucopiae* (Schwager)				■										●	●	●	●	●						
12. *Citharina flabellata* (Gumbel)				■											●	●								
13. *Saracenaria phaedra* Tappan				■												●								
14. *Saracenaria oxfordiana* Tappan				■									●	●	●	●	●							
15. *Marginulinopsis sculptulis* (Schwager)				■											●									
16. *Tristix oolithica* (Terquem)				■												●	●	●	●					
17. *Citharina macilenta* (Terquem)				■											●	●	●							
18. *Lenticulina tricarinella* (Reuss)				■										●	●	●	●	●						
19. *Vaginulinopsis epicharis* Loeblich & Tappan				■												●								
20. *Marginulina nytorpensis* Norling				■											●	●								
21. *Marginulina batrakiensis* Myatliuk				■											●	●								
22. *Epistomina conica* Terquem				■												●	●	●	●					
23. *Epistomina mosquensis* Uhlig				■										●	●	●	●							
24. *Epistomina callovica* Kapterenko-Chernousova				■												●	●							
25. *Citharina tenuicostata* Lutze				■											●									
26. *Frondicularia nikitini* Uhlig				■											●	●								
27. *Epistomina parastelligera* (Hofker)			■	■		■								●	●	●	●	●	●					
28. *Citharina clathrata* (Terquem)						■	■											●	●	●	●			
29. *Reinholdella dreheri* (Bartenstein)						■	■										●	●	●					
30. *Trochammina sablei* Tappan						■													●	●				
31. *Saracenaria trigona* (Terquem)							■													●				
32. *Saracenaria sublaevis* (Franke)							■													●	●	●	●	
33. *Brizalina liasica amalthaea* (Brand)							■														●			
34. *Marginulina spinata interrupta* Terquem							■													●	●	●		
35. *Astacolus neoradiata* Neuweiler							■	■		■											●	●	●	
36. *Ichthyolaria mesoliassica* (Brand)								■													●			
37. *Astacolus denticula carinata* Franke							■	■													●			
38. *Marginulina spinata spinata* Terquem								■	■												●	●		
39. *Citharina inaequistrata* (Terquem)								■	■													●	●	
40. *Haplophragmoides kingakensis* Tappan								■													●			
41. *Geinitzinita tenera tenuistriata* (Nørvang)										■												●	●	
42. *Vaginulinopsis exarata* (Terquem)										■												●	●	
43. *Neobulimina* sp. No. Bang										■												●		
44. *Geinitzinita tenera pupoides* (Nørvang)										■												●		
45. *Reinholdella margarita* (Terquem)										■												●		
46. *Astacolus semireticulata* Norling										■	■											●	●	
47. *Ichthyolaria intercostata* (Kristan-Tollman)											■												●	●
48. *Pseudonodosaria plumiricostata* (Kristan-Tollman)											■												●	●
49. *Reophax eominutus* (Kristan-Tollman)											■												●	●
50. *Tetrataxis inflata* Kristan											■												●	●

Fig. 12.

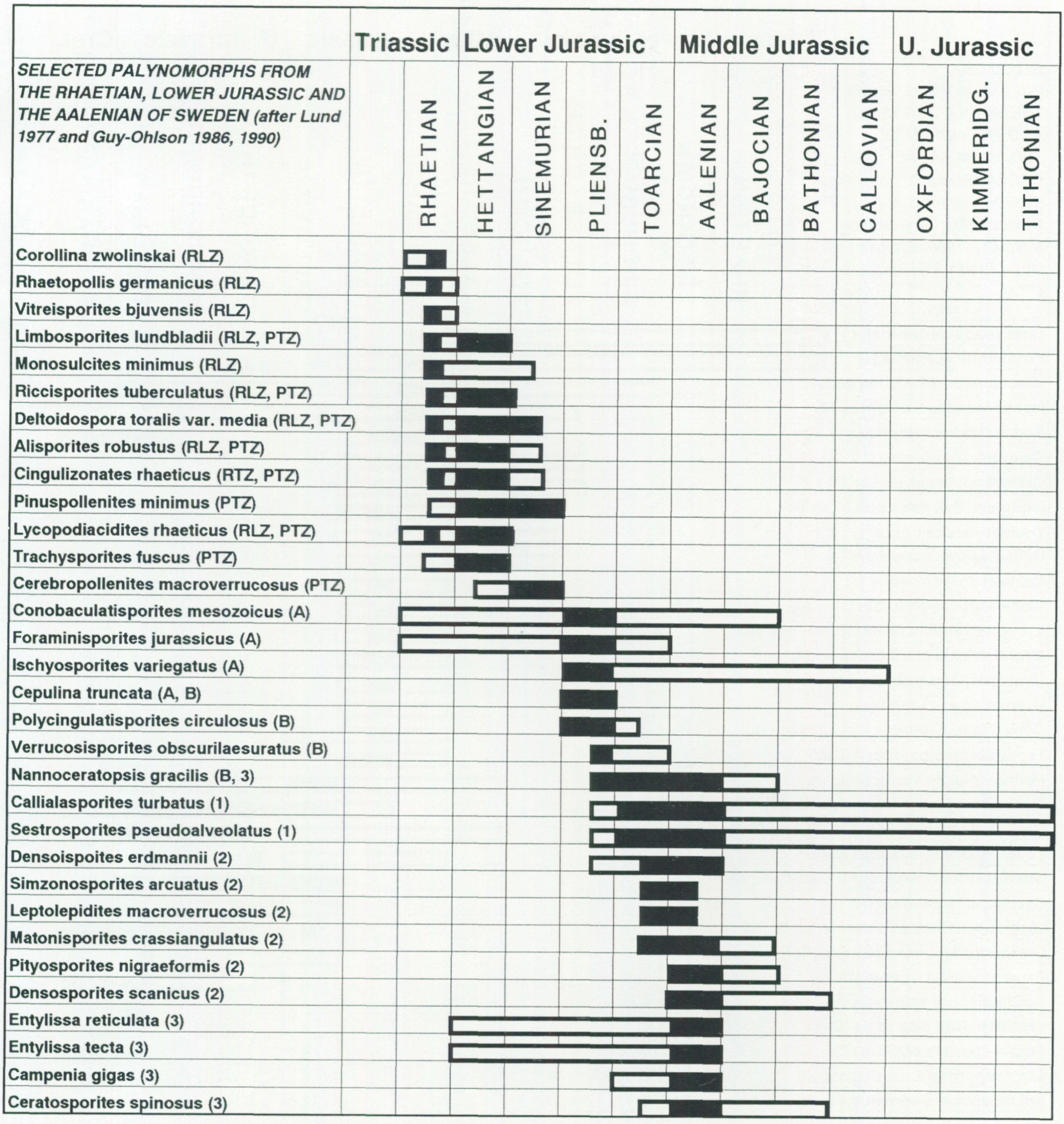


Fig. 13. Selected palynomorphs from the Rhaetian, Lower Jurassic, and the Aalenian of Sweden. Letters and figures in parenthesis after each species refer to the biozones in Figs. 9 and 10. Open range bars show the stratigraphical distribution in Europe, black bars show the range in Sweden.

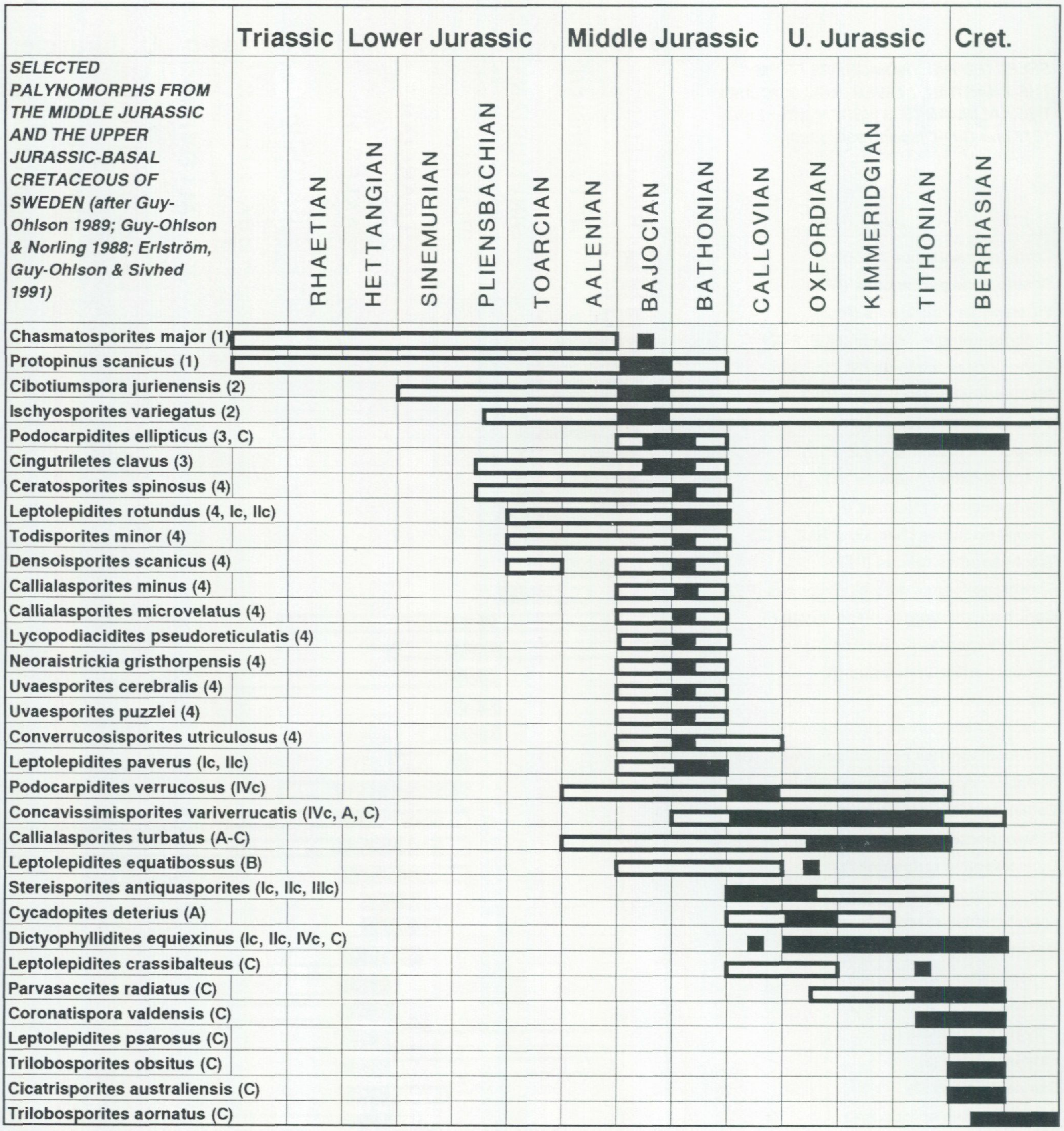


Fig. 14. Selected palynomorphs from the Middle Jurassic and the Upper Jurassic – basal Cretaceous of Sweden. The figures in parenthesis after each species refer to the biozones in Figs. 10 and 11. Open range bars show the stratigraphical distribution in Europe, black bars show the range in Sweden.

Industrial minerals

Several Triassic and Jurassic deposits of minerals and stones used for building have contributed to the economy of the province of Scania. During at least two centuries, coal and fire-clays have been not only of local importance, but of national economic interest.

Coal

The oldest documents concerning mining in Scania are to be found among royal letters from the Danish King Frederik II. In 1561 he sent a privileged letter to a German miner, Jürgen Langnau, who had asked for permission to start mining activities in Kullaberg, NW Scania. Coal has been mentioned in royal letters from 1571 onwards and was at that time mainly used for lighthouse illumination. Melchior Huscher (1571) was the first to inform the Danish king about finds of coal in the vicinity of Helsingborg. This information led to a limited organized coal-mining.

In 1658, when Scania became Swedish, the government established a mine inspector district for Scania with instructions to pay special attention to the mining of coal. In 1663 the Pålsjö shaft near Helsingborg was opened. From 1667 and onwards documents about coal mining at Tinkarp were available. In 1738 coal mining at N. Vallåkra was organized (Fig. 17, p. 34). Miners were recruited from the Falun mining district in the Province of Dalarna, and from Saxony. In 1744 important coal finds were reported from Lunnom (Fig. 22). This coal-field is still in use. In King Adolf Fredrik's coal-field, the amount of coal mined between 1746 and 1796 is reported to have been 58,330 tons. The locations of old coal-fields in Scania are presented in Fig. 15.

In 1786 Erik Ruuth, Finance Minister during King Gustaf III's reign, procured "Skånska Stenkolswerket" (Scanian Coal Mining Company). One of his mining engineers, Anders Polheimer, located the Rhaetian coal-measures (and fire-clay deposits) in the Höganäs area, NW Scania (Fig. 15). It was here that Swedish coal mining on an industrial scale started at the end of the 18th Century. The coal and fire-clay deposits were found at the surface north of Höganäs, but the Rhaetian deposits dip towards the south, which meant that the original surface mining soon had to be replaced by subsurface mining in shafts and adits. The main Rhaetian coal-seam which was mined (B-flöts) is illustrated in Fig. 22 (p. 38).

The 19th century was the golden age for Höganäs. In 1803 glass works were founded making use of the local coal for their activities. The coal was also used for gas

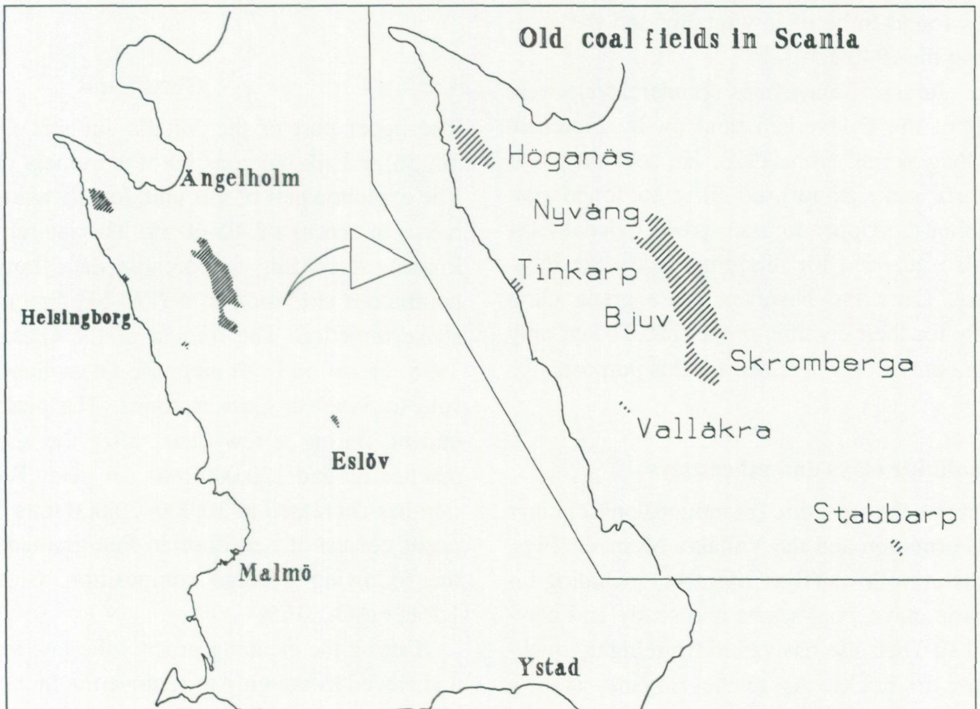


Fig. 15. Location map of the old coal-field in Scania. Compare with geological map, Fig. 1.

works for heating and lightening the households in the town. From the 1880's SJ (Statens Järnvägar = Swedish Railways) started to use Scanian coal. From 1884 to 1905 Scanian coal companies delivered about 85,000 tons of coal per year to SJ. The increasing use of petroleum products, however, made the coal mining in Scania gradually less profitable. In 1961, when the Höganäs Coal Field was abandoned, 7 million tons had been raised. The total Scanian production of coal over the centuries is estimated to 30 million tons (Bergström & Shaikh 1982). Apart from Höganäs, the coal-fields of Bjuv, Nyvång, Billesholm, Lunnom, Vallåkra, Bökeberg, Helsingborg, and Skromberga may be mentioned as coal-fields of importance. Some of them are shown in Fig. 15.

Coal and clay prospecting in the Fyledalen Valley

In 1938 three different competitors applied for licence to mine Middle Jurassic clays and coal in the Fuglunda Member in the Eriksdal area (p. 54). The interest parties were the Höganäs-Billesholm Company, the Lias Syndicate, and Liutenant Bech, owner of the Röddingeberg farm. Numerous investigations focussed on the coal-seams were carried out. The most significant investigation was performed by the Lias Syndicate, later named the Fyleverken Company. This company started mining the main coal-seam, called "Stora kolflötsen", which was one of 13 located seams. The Fyledal coal was found to be of low quality and the quarring ceased during the 1940's.

The Middle Jurassic claystones (underclays) were mined southeast of the Fyleverken sand pit by Liutenant Bech during a long period from 1923. He sold the clays mixed with quartz sand as furnace filler to foundaries. From the beginning the Upper Jurassic green Fyledal Clay (Fig. 11) was also quarried for this purpose by the Fyleverken Company. Later on, however, these green clays were used mainly for their ceramic properties. Today, only a very limited amount of clay is mined for this purpose.

Kaolinitic clays and other clays

In NW Scania, above the smectitic (montmorillonitic) clays of the Kågeröd Formation and the Vallåkra Member (Figs. 22, 23), a succession follows (Bjuv Member) including bituminous kaolinitic clays, coal-seams and sandy and clayish deposits (p. 17). Their use has varied from highly qualified technical use to bricks. As to the Höganäs area, a brickyard and tilery was built in 1825 for production of fire-proof bricks. Factories producing roof tiles, melt crucibles, and lead-glazed earthenwares were also built in the 1820's. The production of salt-glazed pots, which has made NW Scania famous, started on a large scale in 1835 (Fig. 25). Pavement bricks and clinkers of different kinds were produced. Until 1973 some 14 million tons of Rhaetian–Jurassic high-quality clays had been raised from the Höganäs mining field (Bölau 1973; Norling 1982; Sivhed & Wikman 1986; Norling & Wikman 1990).

Building stone, grindstone and millstone production

Different Scanian rocks of Jurassic age have been used for building purposes. Silicified sandstones belonging to the Vittseröd Member of the Höör Sandstone have been mined since the middle of the 11th Century for different purposes (Figs. 8, 16, 35). Lund Cathedral in Roman style is built of this sandstone. The Dalby and Vä churches are partly built of the same rock. Hundreds of Roman baptismal fonts were made of this material. The sandstone has also been used for several church portals and as building-stone for castles and manorhouses (Sundnér 1984). Sandstones of the Hettangian Helsingborg Member have also been quarried to be used as building-stones for churches in SW Scania. The oldest parts of the crypt of Lund Cathedral, for instance are made of this rock. Another example is the Landskrona church.

The arkosic sequences of the Stanstorp Member of the Höör Sandstone of Central Scania (p. 49), have been mined for millstone production (Fig. 35). More fine-grained Hettangian sandstones from the Helsingborg and Vittseröd Members have been used for whetstone fabrication.

Glass Sand

The upper part of the Middle Jurassic Glass Sand (Figs. 10, 36) at Eriksdal consists of extremely clean quartz sand. The exploited part of this unit, locally named Glass Sand A, has a thickness of 40–60 m. The lateral extension is not known. According to borehole data, however, there is a continuous extension in a NW–SE direction, which is the strike direction. The mining of the Glass Sand started in 1938. From the beginning, the Glass Sand production was sold to Swedish glass factories. The peak production, occurring during a few years after the second world war, reached around 120,000 tons per year. Today, the production has decreased to 10,000–20,000 tons. The quarried deposits consist of a medium to fine-grained quartz sand with the following average composition: SiO_2: 97%; Al_2O_3: 1.2%; Fe_2O_3: 0.2% .

During the cleaning process the raw material is washed and sieved thoroughly to remove the thin coatings of kaolinite around the quartz grains. Accessory minerals and heavy minerals (mainly ilmenite and zircon) and iron oxides are removed by centrifugal separation and floatation. The remaining product is split into three different fractions, i.e. glass sand (80% between 0.5 mm and 1 mm), metallurgic sand (80% between 0.3 mm and 0.5 mm), and fine sand (80% < 0.3 mm). Today, the refined products are mainly used in the manufacturing of glass fibres and as components in grinding pastes, road paints, for sand blasting and ceramics.

Iron deposits

The iron-bearing deposits of the Röddinge formation (informal unit, Fig. 36, p. 55) in the Kurremölla valley have been subjected to prospecting during the 1930's and 1940's. The prospecting started after investigations by Professor Assar Hadding (1929, 1933), who found extremely high concentrations of iron in the chamositic and sideritic sandstones. Grängesberg Company acquired the right of option from Hadding in 1930. In 1930–31 the company's investigation was focussed on the area between Kurremölla and Eriksdal (Fig. 37). The results from these investigations were compiled by Hadding (1933) and Palmquist (1935). Later on, in 1937–1940, an exploitation campaign followed, carried out by the so called "Lias Syndicate", which had received the rights of option from the Grängesberg Company. In the northeastern slope of the Fyledalen Valley, some 800 m ESE of Kurremölla, a 100 m long adit was opened. It was found, however, that the iron-rich siderite-oolite was laterally impersistent and repeatedly replaced by iron-poor sandstones. Therefore the Lias Syndicate ended its activities in 1939. From this year on the syndicate's prospecting activities were instead focussed on the Glass Sand and the clays. The option to the iron deposits was transferred to the Höganäs-Billesholm Company, which started a field survey of the complete iron-bearing Jurassic succession in the Eriksdal area. The most interesting zones were investigated from drifts in the Kurremölla Valley. Again, unfavourable results led to the abandoning of the project. Instead, there was an increased interest in mining the coal and clay of the Middle Jurassic Fuglunda Member (Figs. 10, 36).

Fig. 16. The cathedral of Lund is built in quartz cemented Hettangian Höör Sandstone (Photo: Domkyrkans Byggnadskontor, Lund).

(A) EXCURSION LOCALITIES, NW SCANIA

Remarks.- All the map sheets, topographical as well as geological, referred to in the text, are on the scale 1:50,000. The given coordinates refer to the Swedish National Grid to be found on all map sheets mentioned. A location map is given in Fig. 17.

A1. RÖNNEBERGA BACKAR

OBJECTIVE: View of a part of NW Scania.

LOCATION: 8 km NE of Landskrona town.

MAP SHEETS: Topography.- 3C Helsingborg SV. Geology.- SGU Ser Af 149 Berggrundskartan 3C Helsingborg SV (Map of solid rocks).

COORDINATES: 620103/132010.

GEOLOGICAL SETTING: This locality, situated about 100 m a.s.l., is recommended as the first locality during an excursion to the Triassic and Jurassic of NW Scania. It is situated at the boundary between the Fennoscandian Border Zone and the Danish Subbasin, that is at the Scandinavian part of the Tornquist Zone. The lowland to the south and west, with a fairly smooth morphology, represents the Cretaceous-Danian rock surface, covered by Quaternary deposits. Rönneberga Backar is situated within a NW–SE trending zone with a fairly rough topography. This is the western slope of a giant flexure, which includes narrow strips of Lower Jurassic, Middle Jurassic, Upper Jurassic and Lower Cretaceous strata. The flexure, having a width of 4–5 km, forms the boundary between a large regional uplift (Baltic Shield) in the northeast, and a regional area of major subsidence (Danish Subbasin) in the southwest. To the southwest of the flexure the Triassic and Lower Cretaceous strata are succeeded by more or less horizontal layers of Upper Cretaceous to Lower Paleocene (Danian) rocks. In the very flexure, the Lower to Mid-Mesozoic strata dip steeply. The landscape to the north and east of Rönneberga Backar is dominated by Upper Triassic arkoses (Kågeröd Formation) and Silurian shales beneath the Quaternary cover (Fig. 17).

REFERENCES: Bergström *et al.* (1982), Sivhed & Wikman (1986).

A2. BÄLTEBERGA GORGE

OBJECTIVE: Kågeröd Formation. Norian arkosic redbeds.

LOCATION: The outcrop, located 750 m WNW of Bälteberga manorhouse, is a steeply eroded, beautiful gorge linked to the Råån River Valley.

MAP SHEETS: Topography.- 3C Helsingborg SV. Geology.- SGU Ser. Af 149 Berggrundskartan 3C Helsingborg SV (Map of solid rocks).

COORDINATES: 620685/131830.

GEOLOGICAL SETTING: This is the largest of few accessible outcrops with Norian redbeds in Sweden. It is situated within the Höganäs Basin, NW Scania, which at the time of deposition was an intermountainous sedimentary basin. The heterogeneous coarse-grained sediments, viz. conglomerates and arkoses, bear petrographical evidence of syntectonic activities in nearby hinterland areas.

BIOSTRATIGRAPHY AND CHARACTERISTIC FOSSILS: No fossils or trace fossils have been found at this outcrop. This is due to a high rate of sedimentation, a life-hostile palaeoclimate and oxidation of the sediments during and after deposition.

LITHOLOGY AND LITHOSTRATIGRAPHY: At Bälteberga, a typical coarse-grained variety of the Kågeröd Formation dominates. The formation includes wackes, arkoses and paraconglomerates. The wackes comprise smectite-bearing clay minerals, while the arkoses are short-transported first-cycle arenites, primarily derived from nearby gneisses and granites. The conglomerates incorporate arkosic matrices and clasts of Precambrian gneisses and pegmatites, Cambrian quartzitic sandstones and Ordovician-Silurian shales (Hadding 1927). The chemically immature (feldspar rich) sediments of the Kågeröd Formation were preserved due to a high rate of deposition and a dry climate during and after deposition, which hindered chemical weathering.

Resting unconformably on Silurian shales and Precambrian hardrocks, the lower limit of the arkosic Kågeröd Formation in NW Scania is easily recognized. The transition from the Kågeröd Formation to the superimposed coal-bearing Höganäs Formation is likewise distinct, due to a distinct change in the style of weathering (from arid to humid conditions).

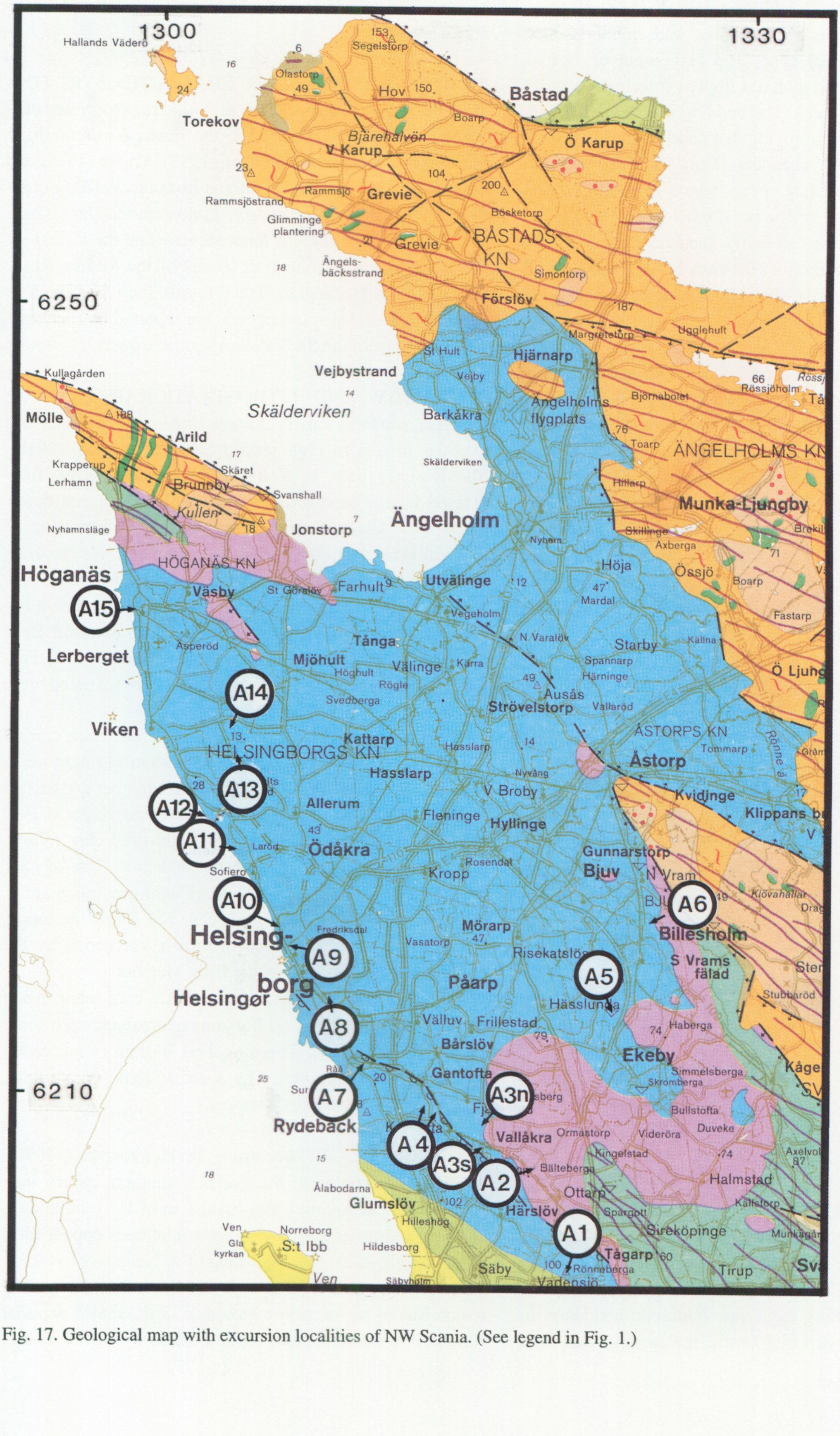


Fig. 17. Geological map with excursion localities of NW Scania. (See legend in Fig. 1.)

SEDIMENTOLOGY: The Bälteberga redbeds were probably deposited as debris flow lobes and minor braided channels on an alluvial cone. The high input of various kinds of coarse-grained material imply syntectonic activity in nearby hinterland areas. The bedding is characterized by amalgamating troughs implying that debris flows were concentrated in confined channels (Lena Adrielsson 1992, Lund Geological Institute, pers. comm.). Some bedsets have a fining-up trend with a basal erosional surface and a basal paraconglomerate. Roughly speaking, the sediment transport directions were from the east. Some small channel troughs were temporarily abandoned and filled with finer sediments (wackes).

DIAGENESIS: The strata exposed at Bälteberga are deeply weathered. When seen in a fresh state, the lithology is reddish due to a high feldspar content and widespread haematite cementation. During early diagenesis, haematite rims were formed around the detrital grains due to repeated wetting and drying in the oxidizing zone of the sedimentary column. Minor patches of calcite cement were formed in the sediment during further burial. New fluid inclusion data of calcite cements imply that the Kågeröd Formation was never subjected to temperatures higher than 90° C (Ahlberg, unpublished data).

REFERENCES: Norin (1949), Norling & Wikman (1990), Sivhed & Wikman (1986), Troedsson (1942).

A3. VALLÅKRA QUARRIES

OBJECTIVE: Vallåkra, Bjuv and Helsingborg Members, Höganäs Formation, Rhaetian, Upper Triassic to Hettangian, Lower Jurassic.

LOCATION: About 12 km SE of Helsingborg centre.

MAP SHEETS: Topography.- 3C Helsingborg SV. Geology.- SGU Ser. Af 149 Berggrundskartan 3C Helsingborg SV (Map of solid rocks).

COORDINATES: Vallåkra southern quarry: 3C Helsingborg 62080/13155. Vallåkra northern quarry: 3C Helsingborg 62087/13156.

GEOLOGICAL SETTING: At Vallåkra, Rhaetian and Hettangian sedimentary rocks referred to the Höganäs Formation can be seen. In the northern quarry sediments of the Vallåkra, Bjuv and Helsingborg Members are exposed, that is a sequence straddling the Triassic/Jurassic boundary. In the southern quarry deposits named the Boserup beds can be seen. These beds form a part of the Hettangian Helsingborg Member.

BIOSTRATIGRAPHY AND CHARACTERISTIC FOSSILS: In the southern quarry at Vallåkra, footprints of a dinosaur (Fig. 19) belonging to the genus *Grallator* have been found (Gierlinski & Ahlberg 1993). Tralau (1975) and Lund (1977) described microfloras from the Vallåkra quarries. As to the northern quarry, Lund referred the stratum studied to the *Rhaetopollis limbosporites* and the *Riccisporites polyodiisporites* miospore Zones of the Middle Rhaetian and basal Hettangian. Trace fossils such as *Planolites* and *Pelecypodichnus (=Lockeia)* are reported by Pieńkowski (1991b) from the the Vallåkra southern quarry.

LITHOLOGY AND LITHOSTRATIGRAPHY: In the Vallåkra southern quarry Lower Jurassic heterolites are exposed in a 6 m high profile (see Pieńkowski 1991b). The Boserup beds at Vallåkra represent a distal, fine-grained facies. Eastwards, the beds in question are dominated by a sandy, fluvial facies. In the northern part of the Vallåkra area, the Vallåkra, Bjuv and Helsingborg Members (Höganäs Formation) can be studied. In the valley of a small rivulet (near a car parking place), strata belonging to the uppermost part of the Vallåkra and Bjuv Members are exposed. Different parts of the Höganäs Formation are seen in several small outcrops scattered over this area.

No detailed lithological investigation has been carried out in the Vallåkra area. A brief presentation might be as follows: The basal part of the Vallåkra Member consists of 6 m sand and clay resting on redbeds of the Kågeröd Formation (Norian). Then, c. 5 m of light-grey clay follow, succeeded by 3 m of argillaceous sandstone, 1 m of dark clay, 1 m of sphaerosiderite, 1 m of light-grey clay, and 1 m of dark clay. The upper dark clay bed forms the top of the Vallåkra Member, which in turn is succeeded by the basal coal-seam (B-flöts) of the Bjuv Member.

The Bjuv Member thus starts with a coal-seam, made up of two 10 cm thick coal horizons intercalated with some 15 cm of black shale. This so called B-seam is succeeded by c. 25 m of sandstones. The A-seam, some 10 cm thick marks the top of the Bjuv Member.

SEDIMENTOLOGY: According to Pieńkowski (1991b), the deposits exposed at the Vallåkra southern quarry may be described as follows: The basal 1 m of the section consists of sandstones and sandy, heterolitic beds deposited in a periodically emerged environment as indicated by dessication cracks, rootlet beds and vertebrate foot prints. The major part of the section exposed, c. 5 m, shows deposits formed in a shallow, calm basin affected by waves. A thin

Fig. 18. Visiting the Vallåkra Ceramic Studio is an enjoyable experience. Photo: Y. Arremo, Swedish Museum Nat. Hist.

layer (0.4 m) of sandstone with numerous bivalves in a poor state of preservation forms the top of this section. No modern sedimentological analysis has been made in the northern Vallåkra quarry as this locality is poorly exposed.

REMARKS: The argillaceous parts of the Höganäs Formation at Vallåkra have been mined ever since the beginning of the 18th Century. Various ceramic products have been, and still are, produced from kaolinitic clays from this formation (see p. 30). At Vallåkra, a small ceramic studio with a long tradition is still in use. A similar pottery using "Vallåkra clays" is located at Raus, a southern suburb of Helsingborg (p. 42). Furthermore, the Vallåkra clays have been used for aluminium sulphate production. The coal of the Bjuv Member at Vallåkra has been mined since the 1730's.

REFERENCES: Lund (1977), Pieńkowski (1991b), Sivhed (1984), Sivhed & Wikman (1986), Troedsson (1913, 1943, 1951).

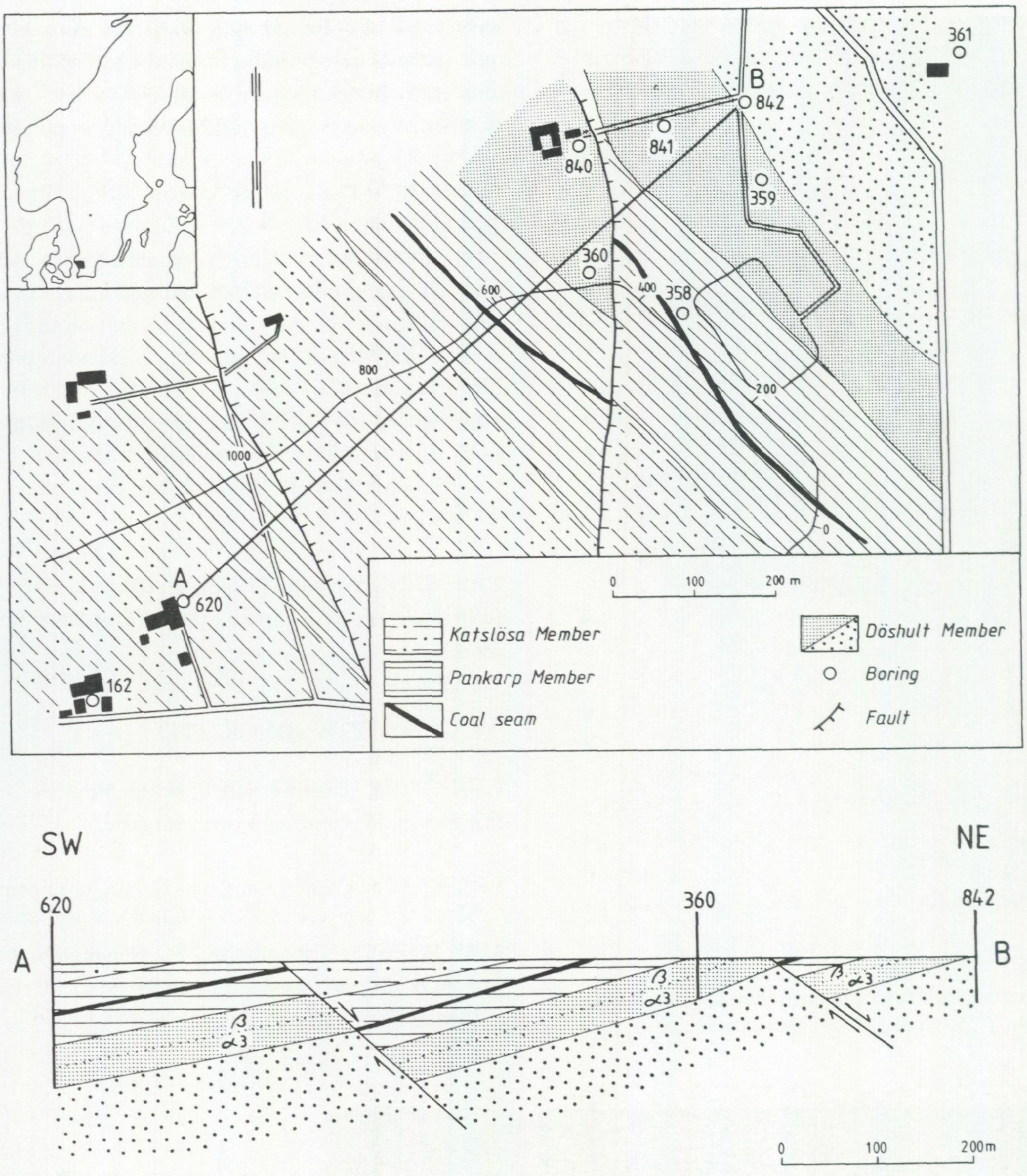
A4. GANTOFTA BRICK PIT

OBJECTIVE: Döshult and Pankarp Members of the Rya Formation, Sinemurian, Lower Jurassic.

LOCATION: About 9 km SE of Helsingborg centre.

MAP SHEETS: Topography.- 3C Helsingborg SV. Geology.- SGU Ser. Af 149 Berggrundskartan 3C Helsingborg SV (Map of solid rocks).

Fig. 19. Dinosaur footprints at Vallåkra southern quarry (Hettangian). Locality A3. Photo: U. Sivhed.



a

b

Fig. 20. a) Jurassic geology of the Gantofta area. b) Geological cross-section between A and B on the map above. α_3 = L. Sinemurian, β = U. Sinemurian (after Sivhed 1981).

COORDINATES: 620980/131290.

GEOLOGICAL SETTING: For a long time the Gantofta–Katslösa area has been the subject of geologists' attention. In 1945 a ditch system was dug between the two villages. The deposits exposed were sampled and measured by Troedsson (1951). During the 1950's and 1960's the Höganäs Company carried out a detailed geological investigation in the Gantofta–Katslösa area (Bölau 1973). This survey resulted in the opening of a brick pit at Gantofta. Later studies of the Jurassic geology in this area have been reported by Norling (1972) and Sivhed (1980, 1981).

In the Gantofta area sedimentary rocks referred to the Döshult, Pankarp and Katslösa Members of the Rya Formation are covered by a thin layer of Quaternary deposits. The Liassic beds strike N 45° E and have a main dip between 15° and 25° to the southwest. Two strike-slip faults have been observed in the area, one in the western part and one further to the east. The western fault has a strike of about N 65° W. The dip is unknown. The eastern fault has a strike of about N 35° E, a throw of 35 m and a heave of 50 m. The throw of the western fault has been calculated to 55 m, and the heave to 65 m.

BIOSTRATIGRAPHY AND CHARACTERISTIC FOSSILS: Norling (1972) described a foraminiferal fauna from a bed of the Döshult Member rich in the oyster *Liogryphaea arcuata*. The foraminifers were dated to Early Sinemurian (Fig. 12, Appendix I). This sequence, known as the *Liogryphaea* beds is still accessible, after removing a thin soil cover.

Reyment (1969a, b) described an ammonite fauna obtained from the upper part of the Döshult Member, close to the base of the succeeding Pankarp Member. This fauna includes *Asteroceras obtusum*, denominator of an ammonite zone of the Upper Sinemurian (Fig. 9). The boundary between the Döshult Member and the Pankarp Member has been placed 2 m above this horizon.

Lund (1977) described palynomorphs from samples taken at Gantofta, characterizing the Lower Sinemurian and Upper Sinemurian respectively, e.g. *Cerebropollenites macroverrucosus* and *Trachysporites fuscus*. The ostracode fauna of the Gantofta Brick Pit has been treated by Sivhed (1977, 1981). Species such as *Christacythere betzi, C. crassireticulata* and *Ogmoconchella danica* are ostracode zone fossils of the Lower Sinemurian to basal Pliensbachian (Fig. 9, Appendix II). This fauna has been obtained from the Döshult Member. So far, no ostracodes have been recorded from the Pankarp Member at this locality.

LITHOLOGY AND LITHOSTRATIGRAPHY: Previously, deposits belonging to the Döshult and Pankarp Members were exposed in the Gantofta Brick Pit. At the present day, only parts of the Döshult Member are exposed, including a dark grey, marly shale with intercalations of siltstone rich in trace fossils. During the mining of marls and clays, a 35 m thick sequence of the Döshult Member was exposed and some 10 m of the Pankarp Member, the latter represented by variegated clays. At that time numerous carbonate concretions with diagenetic cone-in-cone structures were recorded in the Döshult Member.

SEDIMENTOLOGY: The lower part of the Döshult Member in the Gantofta Brick Pit represents a marine, gradually deepening environment. Fossiliferous sandstones, named *Liogryphaea* beds, and shale deposits were formed in a sublittoral environment and an open marine basin, respectively. The latter were deposited below the storm wave-base.

REMARKS: In the Gantofta Brick Pit, the Höganäs Company has mined clays from the Pankarp Member for brick production.

Near the Gantofta Brick Pit (map sheet 3C Helsingborg SV, coordinates 620947/131350), a bedrock surface (Döshult sandstone) can be seen which is covered with grinding furrows from axe sharpening. These furrows (Fig. 21) are regarded to be of Neolithic age (Troedsson 1951).

West of the Gantofta Brick Pit, the youngest outcropping Jurassic strata of NW Scania can be studied in a temporarily exposed road section, known as the Katslösa Road Exposure (coordinates 3C Helsingborg SV 620935/131180). This section, presently hidden by a thin vegetation cover, includes ferruginous sandstones, marls and claystones referred to the Katslösa Member, Rya Formation. A meagre foraminiferal fauna was recorded by Norling (1972). The fauna contains species such as *Ichthyolaria mesoliassica* (Brand) and *Brizalina liasica* (Terquem), indicating a Pliensbachian age (Fig. 12).

REFERENCES: Bergström *et al.* (1982), Bölau (1973), Erdmann (1874), Ledje (1985), Lund (1977), Norling (1972), Pieńkowski (1991a, 1991b), Reyment (1969a, b), Sivhed (1977, 1980, 1981, 1984), Troedsson (1951).

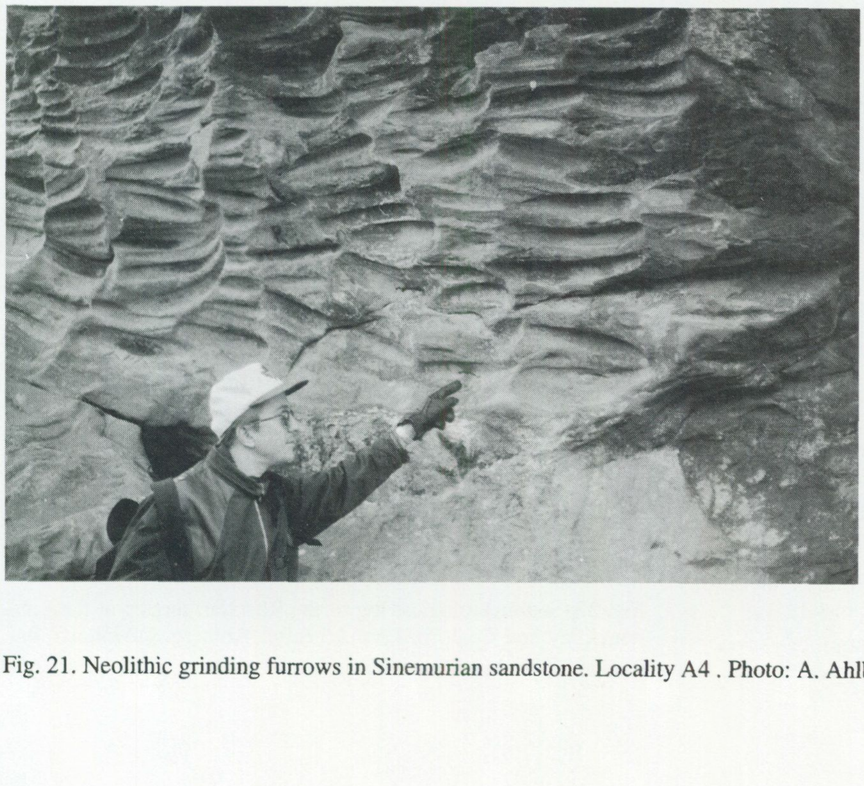


Fig. 21. Neolithic grinding furrows in Sinemurian sandstone. Locality A4 . Photo: A. Ahlberg.

A5. LUNNOM CLAY AND COAL PIT

OBJECTIVE: Bjuv Member, Höganäs Formation. Rhaetian underclay, coal and arenites.

LOCATION: About 8 km south of Bjuv centre, 300 m east of road 110.

MAPS SHEETS: Topography.- 3C Helsingborg SV. Geology.- SGU Ser Af 149 Berggrundskartan 3C Helsingborg SV (Map of solid rocks).

COORDINATES: 621450/132250.

GEOLOGICAL SETTING: The Lunnom quarry exhibits a Rhaetian palaeosol and arenites at the transition between the Vallåkra and Bjuv Members of the Höganäs Formation.

BIOSTRATIGRAPHY AND CHARACTERISTIC FOSSILS: In terms of palynostratigraphy the entire Bjuv Member is referred to the *Rhaetipollis-Limbosporites* Miospore Zone of the Middle Rhaetian (Lund 1977). Lundblad (1959) defined the palaeobotanical transition between the Rhaetian and the Hettangian as the replacement of *Lepidopteris ottonis* by *Thaumatopteris schenki.* Molluscs, arthropods and fish remains have also been obtained from the Bjuv Member (Bölau 1949, Troedsson 1951), as well as tridactyl dinosaur footprints (Gierlinski & Ahlberg 1993). At Lunnom, a determinable macroflora is rare. Fossil roots penetrating the palaeosol below the coal-seam are common and large fossil wood logs are occasionally exhibited during mining.

LITHOLOGY AND LITHOSTRATIGRAPHY: During several years the open quarry has been strip-mined for kaolinitic underclays (extremely rich in Al) and coal assigned to the B-coal-seam. This palaeosol has been recorded throughout the Höganäs Basin and marks the lower boundary of the Bjuv Member. Continuously a 7 m high section is exposed at Lunnom (Fig. 22). At its base a kaolinitic underclay dominates. Abundant rootlets extend from the superimposed coal bed and penetrate the underclay. The palaeosol (i.e. the underclay and the autochtonous coal-seam) is followed by lenticularly bedded mudstone rich in small scale ripplemarks and trace fossils (*Pelecypodichnus* (=*Lockeia*) and *Planolites*). The muddy heterolites grade upwards in the sequence into flaser bedded sandstone. This unit is rich in small scale ripplemarks and has yielded a few traces of animal locomotion (*Planolites* and *Rhizocorallium*). The section is completed by a continuous layer of siderite cemented sandstone.

SEDIMENTOLOGY: According to Ahlberg & Arndorff (unpublished data), the lowermost part of the profile comprises a root-bioturbated underclay and a coal-seam which together constitute a palaeosol developed on a floodplain. Small-scale sandfilled channels drained the floodplain, and are occasionally found as interbedded sandstone lenses encased in the palaeosol. Due to sediment compaction, the palaeosol was flooded by a floodplain lake and covered by subaqueous lacustrine sediments, i.e. ripple-drift crosslaminated heterolites and bedded mudstones, which occasionally were bioturbated by invertebrates. The presence in this part of the profile of organic rich mudstones with early diagenetic siderite, and the lack of bioturbation, imply sporadic stagnant fresh water conditions of the floodplain lake.

DIAGENESIS: Some arenites contain large amounts of authigenic kaolinite. Vitrinite reflectance measurements (Rm) of coal sample from Lunnom yielded 0.5%. This implies that the strata experienced temperatures of 90°–100°C at the most (Ahlberg, unpublished data).

REFERENCES: Pieńkowski (1991 b), Sivhed (1984, 1986), Svensson (1989).

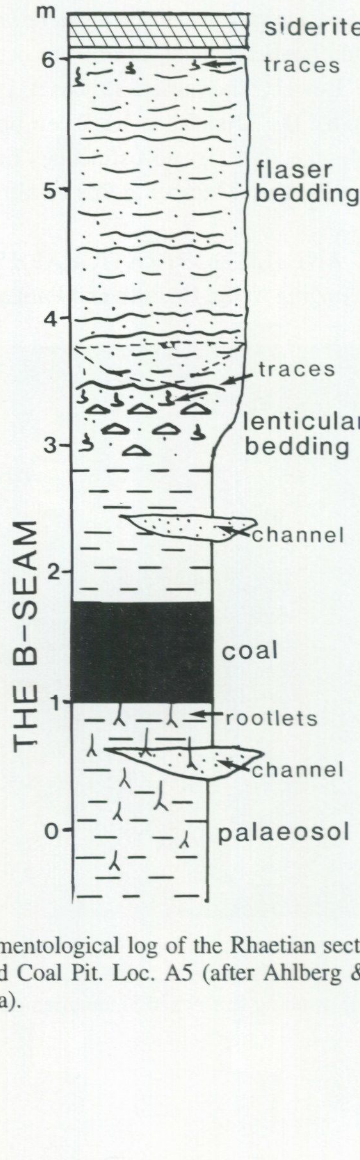


Fig. 22. Sedimentological log of the Rhaetian section at the Lunnom Clay and Coal Pit. Loc. A5 (after Ahlberg & Arndorff, unpublished data).

A6. NORRA ALBERT CLAY AND COAL PIT

OBJECTIVE: Bjuv and Helsingborg Members, Höganäs Formation. Rhaetian coal-bearing palaeosols and fluid arenites and Hettangian fluvial arenites.

LOCATION: N. Albert is located 1.5 km N. of Billesholm village, west of the Söderåsen horst (Fig. 17).

MAP SHEETS: Topography.- 3C Helsingborg SV. Geology.- SGU Ser. Af 149 Berggrundskartan 3C Helsingborg SV (Map of solid rocks).

COORDINATES: 621940/132440.

GEOLOGICAL SETTING: The Norra Albert quarry shows the transition from Rhaetian interbedded coal-seams, mudstones and arenite lenses (Bjuv Member) to Hettangian coarse-grained arenites (lowermost Helsingborg Member), Höganäs Formation in the Höganäs Basin.

BIOSTRATIGRAPHY AND CHARACTERISTIC FOSSILS: The same as for the Lunnom Clay and Coal Pit (A5).

LITHOLOGY AND LITHOSTRATIGRAPHY: A 14 m profile is currently exposed in the Norra Albert quarry. A set of four stacked palaeosols (alternating mudstones and coal-seams) with minor sandstone channels has been observed at the lower part of this profile (Ahlberg & Arndorff, unpublished data). Lateral strip-mining recently uncovered a 50–100 m wide and a 3 m thick channel-shaped sandstone lens, interbedded within the palaeosols. The coal-bearing interval is followed by several metres of trough cross-bedded coarse-grained submature sandstone. The top of the uppermost coal-seam (A-seam) is the arbitrary Rhaetian–Hettangian boundary (Sivhed 1984).

SEDIMENTOLOGY: The Rhaetian palaeosols were formed in a stable low-relief alluvial plain. Occasionally, small streams deposited sand in well confined channels and by minor crevasse splays due to overbank flooding. Fluctuating rates of clastic contents of the peat (i.e. ash content of the coal) imply sedentary accretion of plant material, below or above the ground water table (Arndorff & Ahlberg, unpublished data). Flame structures of the uppermost coal-seam (Rhaetian) indicate that the deposition of the superimposed Hettangian sandstones occurred prior to compaction (dewatering) of the palaeosols. This is surprising since a regional upper Rhaetian hiatus has been inferred (Lund

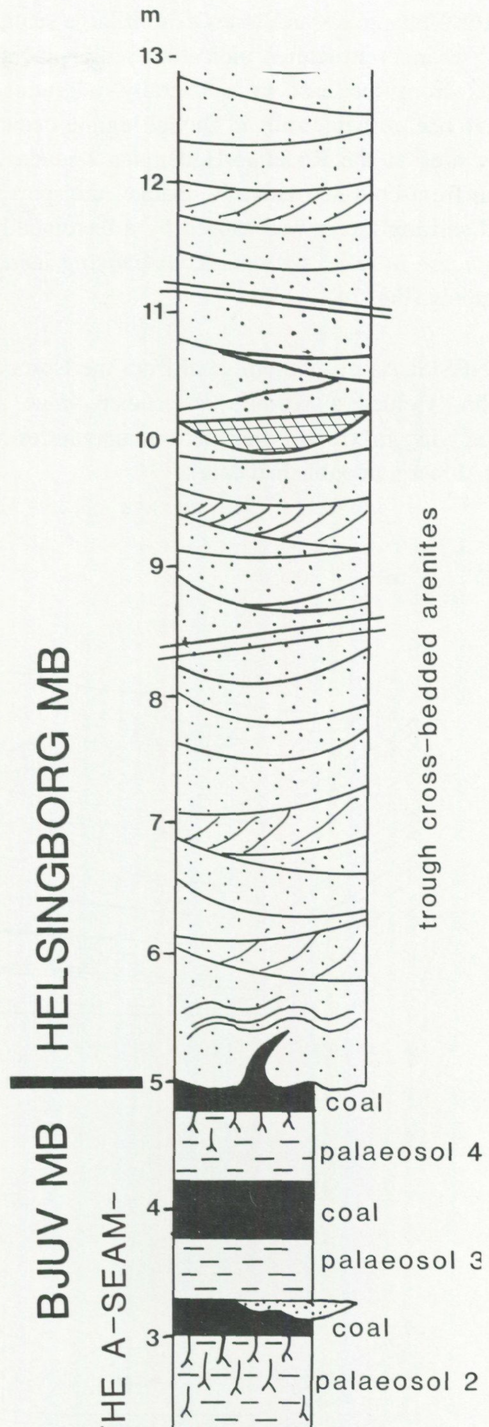


Fig. 23. Sedimentological log of the Rhaetian–Hettangian section at Norra Albert. Locality A6 (after Ahlberg & Arndorff, unpublished data).

1977). The Hettangian sandstones exhibit large scale amalgamating channel structures indicating sediment transport directions from the east in a laterally migrating river system. Hence, a major shift in fluvial regime occurred in the Bjuv area at the Rhaetian-Hettangian boundary. The transition from confined laterally channel transport to unconfined shifting rivers was caused by a tectonically triggered increase in relief with an accompanying increase in clastic supply (Fig. 24).

DIAGENESIS: As in Lunnom, coal from the Norra Albert quarry has yielded a vitrinite reflectance value around 0.5%, implying maximum diagenetic temperatures around 100° C (Ahlberg, unpublished data).

REFERENCES: Ahlberg (1990), Pieńkowski (1991b), Sivhed & Wikman (1986).

REMARKS: In Bjuv there is a mining museum of interest to visit, some 4 km NW of Locality A6. This museum is recommended for its interesting display of the local bedrock and mining history. Address: Ågatan, Shaft 3. Telephone: 042-85233. Opening hours 10.00–16.00 hours (summertime). During other seasons, visitors may be taken on guided tours (telephone booking necessary), by special arrangements (Tel. 042-85000).

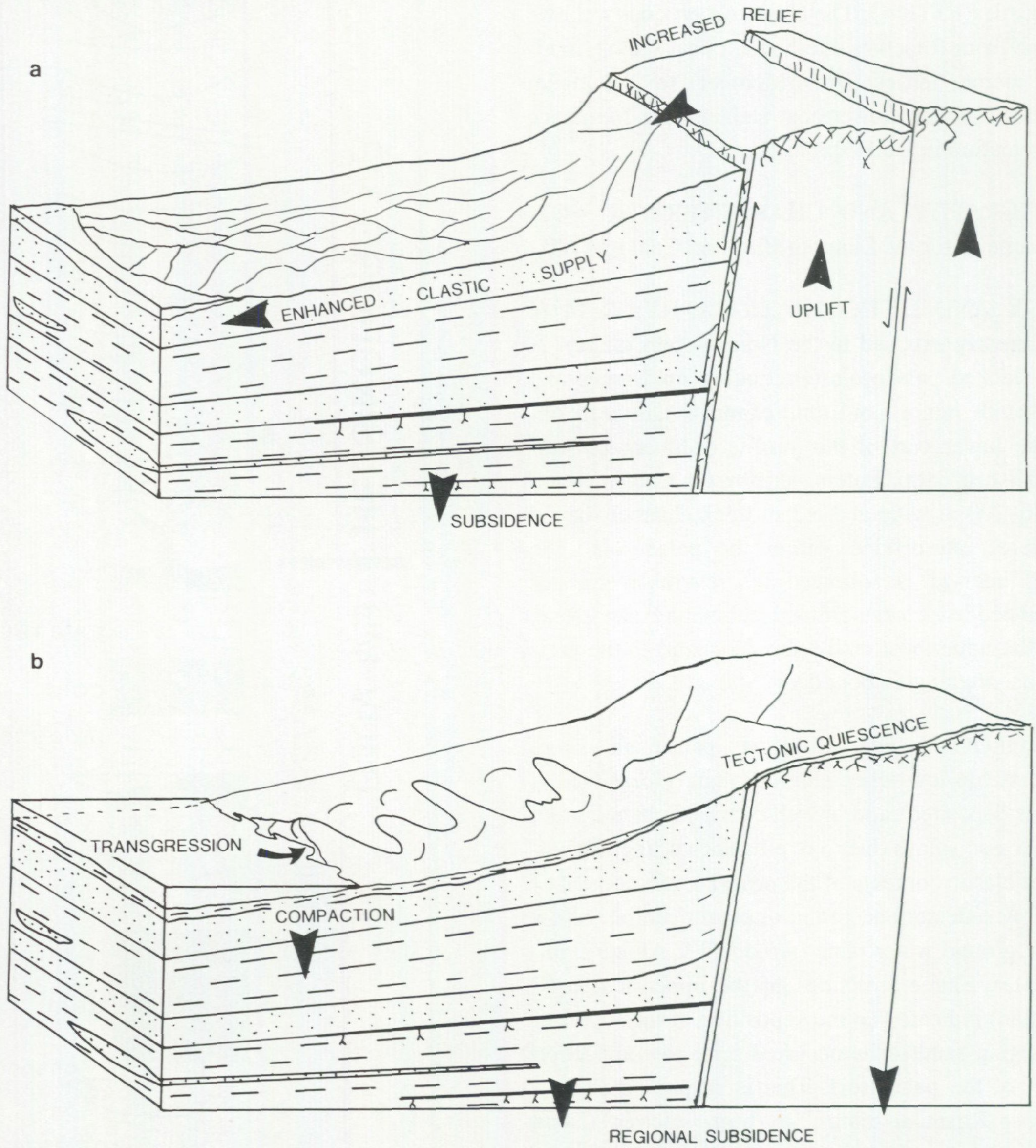


Fig. 24. The deposition was dependent on the lateral versus vertical accretion ratio. Near the source area of the sediments, strong clastic influx pulses gave unconfined lateral accretion of coarse sediments (a). Tectonic quiescence and subsidence led to vertical accumulation of fine sediments. Compactional subsidence and eustatically rising sea-level caused transgressions (b). Locality A6, Norra Albert Clay and Coal Pit (after Ahlberg 1990).

Fig. 25. Mr Lars Andersson, owner of the Raus Stoneware Work (locality A7), scrutinizes newly fired salt-glazed pots. Photo: E. Norling.

Fig. 26. Raus Stenkärlsfabrik (locality A7). Pots prepared for firing. Photo: E. Norling.

A7. RAUS STENKÄRLSFABRIK

OBJECTIVE: Pottery based on local Upper Triassic (Rhaetian) fire-clays.

LOCATION: At Raus, a suburb of Helsingborg, about 6 km SE of the Helsingborg city centre.

REMARKS: The tradition of making salt-glazed stonewares was introduced to NW Scania from Germany in the 18th Century where it had been practised in the Rhine district since the 13th Century. The Helsingborg Stoneware Factory was founded in the 1790s. During the following century stoneware factories in Höganäs, Vallåkra, Skromberga and Raus were built. During a short period (1802–1806), the town of Ystad in south Scania also had such a factory run by German potters.

Raus Stenkärlsfabrik (Raus Stoneware Work) was built in 1911–1912 by Mr. Ludwig Alfred Johnsson who had received his experience in pottery in the USA, where he lived for five years. When he died in 1946, the factory was taken over by three men from the permanent staff of the factory, Hugo Anderberg, Knut Mellby and Olof Nilsson. These men restored the factory and their products soon became coveted. From the 1960s the demand has been on the increase. The salt-glazed pots were originally used for preserving fish, fruits, as well as salted and pickled vegetables. At the present day they are mainly bought for decoration. The present owner of the Raus stoneware factory, Lars Andersson, is an apprentice of the late Mr. Anderberg. Lars Andersson, his wife and employees are skilful potters keeping the fine NW Scanian stoneware tradition at a first-rate quality level.

The crude material used for turning pots is a Middle Rhaetian fire-clay taken from outcrops in the nearby Råå river valley. Another pottery in the vicinity of Helsingborg, which is also worth a visit, is Wallåkra Stenkärlsfabrik at Vallåkra. This studio, having still older tradition in salt-glazed pottery, uses the same type of Rhaetian fire-clays.

TELEPHONE No.: 042-260130.

REFERENCES: Guy-Ohlson (1984), Sivhed & Wikman (1986), von Friesen (1976).

A8. HELSINGBORG OLD CLAY PIT

OBJECTIVE: Helsingborg Member, Höganäs Formation. Hettangian deltaic sediments.

LOCATION: In the southern part of Helsingborg City, SE of the Lägervägen-Stenbocksgatan road-crossing.

MAP SHEETS: Topography.- 3C Helsingborg SV. Geology.- SGU Ser. Af 149 Berggrundskartan 3C Helsingborg SV (Map of solid rocks).

COORDINATES: 621625/130735

GEOLOGICAL SETTING: This locality is situated in the Höganäs Basin. The strata are tentatively assigned to cycle No. 7 of the Höganäs Formation (sensu Troedsson 1951. See also Vossmerbäumer 1969 and Pieńkowski 1991b).

BIOSTRATIGRAPHY AND CHARACTERISTIC FOSSILS: The Helsingborg Member is referred to the Hettangian by the presence of *Thaumatopteris schenki* (megafossil zone; Lundblad 1959) and the *Pinuspollenites-Trachysporites* Miospore Zone (Lund 1977). The Helsingborg Member has yielded bivalves, fish remains, arenaceous foraminifera, dinosaur footprints and a lacustrine to restricted marine invertebrate trace fossil assemblage.

At Helsingborg Old Clay Pit (Helsingborgs Gamla Ångtegelbruk) charred roots and invertebrate trace fossils are abundant. Horse-tails (*Equisites*) have been found in living position.

LITHOLOGY AND LITHOSTRATIGRAPHY: The strata exposed at this locality are typical for most sections in the Helsingborg Member. They are comprised of mudstones with rootlets, thin autochthonous and allochthonous coal-seams, lenticularly and wavy bedded mudstones and mature fine-grained arenites. The assignment of these strata to Troedsson's cycle No. 7 must be regarded as tentative, since the facies types of the Helsingborg Member are repetitive and because the Helsingborg area has been subjected to extensive vertical faulting.

SEDIMENTOLOGY: The facies at this locality neatly reflects changes between subaerial exposure (resulting in palaeosols) and subaqueous deposition in a weakly agitated delta distributary brackish-marine bay or lagoon. Active sediment-filling of the bay by crevasse splays or delta distributary channels has left shallowing-upwards sequences capped by palaeosols revealing subaerial exposure. Completion of the bay-filling was accompanied with abandonment (lateral shifting) of sediment supply channels. Hence,

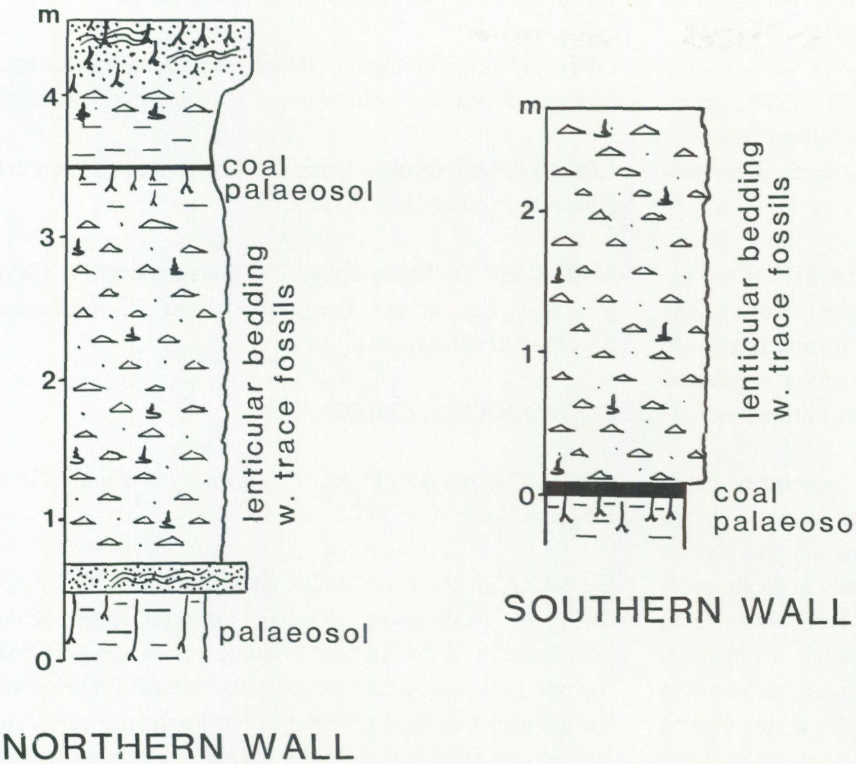


Fig. 27. Sedimentological logs of the Hettangian sections at Helsingborg Old Clay Pit. Locality A8.

early sediment compaction outweighed sedimentation and the sediment-filled bay was again overstepped by calm brackish-marine waters. This is reflected by abrupt changes from subaerial to subaquaceous strata in the sections exposed at Helsingborg Old Clay Pit.

At the northern wall of the quarry a 6 m high sedimentary column is exposed (Fig. 27). At the base lenticularly bedded (wave agitated) mud- and siltstones with bivalve dwelling and locomotion traces (*Pelecypodichnus* and *Imbrichnius*) are conformably followed by homogeneous mudstone with abundant rootlets. The palaeosol is sharply cut off by a sand sheet reworked by waves. The latter bears signs of combined unidirectional sediment transport and wave agitation. The sandstone is succeeded by lenticularly bedded (wave agitated) mud- and siltstone with bivalve traces, indicating renewed subaqueous deposition. The lenticularly bedded interval is interrupted by a thin, poorly developed muddy palaeosol with rootlets. The brief subaerial exposure is again followed by subaqueous deposition in a weakly agitated environment. Towards the top of the profile a gradual coarsening-up transition from lenticular bedded mudstone to flaser bedded sandstone with upwards increasing root bioturbation indicates microdelta progradation (shallowing) into the muddy bay.

In the southern wall of the quarry a small exposure reveals similar strata as in the northern wall. An additional feature is a well developed 20 cm thick coal-seam. The strata at Helsingborg Old Clay Pit have been described by Vossmerbäumer (1969, 1970) and Pienkowski (1991b).

REFERENCES: Ahlberg (1990), Pieńkowski (1991b), Vossmerbäumer (1969, 1970).

A9. HALALID ROAD CUTTING, HELSINGBORG

OBJECTIVE: Höganäs Formation, Helsingborg Member, Hettangian, Lower Jurassic.

LOCATION: Road cutting in the northern part of Helsingborg City.

MAP SHEETS: Topography.- 3C Helsingborg SV. Geology.- SGU Ser. Af 149 Berggrundskartan 3C Helsingborg SV (Map of solid rocks).

COORDINATES: 621895/130560.

GEOLOGICAL SETTING: The Hettangian deposits of NW Scania represent a transgressive phase. Sediments resulting from meandering rivers, deltaic, lagoonal and nearshore environments, as well as beach barriers, are to be found in the area. The entire Helsingborg Member has a total thickness of about 200 m. In Hettangian times, the mainland was situated in the east. The deposits at Halalid represent a deltaic environment (Pieńkowski 1991a).

BIOSTRATIGRAPHY AND CHARACTERISTIC FOSSILS: No diagnostic fossils have been identified from this section. Its dating is based on lithostratigraphical correlation.

LITHOLOGY AND LITHOSTRATIGRAPHY: The exposed section shows sandstones rich in plant detritus. The strata are classified as arkosic wackes and subarkoses. On lithostratigraphical grounds the Halalid section is referred to the Helsingborg Member of the Höganäs Formation.

SEDIMENTOLOGY: The road cutting penetrates sandstones entirely consisting of bedsets of tabular and trough cross-bedded arenites with mud drapings on the foreset beds (Fig. 28). The foreset beds invariably indicate sediment transport towards the west, that is basinwards. Each bedset was deposited by a migrating sandwave or subaquatic sand dune and was partly eroded by the migration of the subsequent one. The sand and mud bundles of the foreset beds may be of intertidal origin (mud drapings on the foresets deposited during neap-tide periods). The sand was deposited in a delta distributary channel, or in an ebb delta of a lagoonal tidal channel.

REFERENCES: Ahlberg (1990), Erdmann (1911-15), Pieńkowski (1991b), Sivhed (1984), Sivhed & Wikman (1986), Troedsson (1947, 1951).

A10. HÄLSAN GORGE, HELSINGBORG

OBJECTIVE: Hettangian deltaic sediments, Helsingborg Member, Höganäs Formation.

LOCATION: Exposure along the Landborgen escarpment, Hälsovägen road, Helsingborg.

MAP SHEETS: Topography.- 3 C Helsingborg SV. Geology.- SGU Ser Af 149 Berggrundskartan 3C Helsingborg SV (Map of solid rocks).

COORDINATES: 621800/130600.

GEOLOGICAL SETTING: This locality is situated in the Höganäs Basin (Fig. 17).

BIOSTRATIGRAPHY AND CHARACTERISTIC FOSSILS: The Helsingborg Member is referred to the Hettangian because of the finds of *Thaumatopteris schenki* (macrophyte zonation by Lundblad 1959). In terms of miospores the member has been referred to the *Pinuspollenites-Thrachysporites* Zone (Lund 1977). A typical Hettangian microflora was reported from the Hälsan Gorge by Lindström (1987b). The Helsingborg Member has yielded bivalves, fish remains, dinosaur footprints and a lacustrine to restricted marine invertebrate trace fossil assemblage. Foraminifers are rare. Most records concern arenaceous forms such as *Ammodiscus asper* Terquem, *Reophax eominutus* (Kristan-Tollmann), *R. horridus* (Schwager) and *Tetrataxis inflata* Kristan. At one locality only, calcareous foraminifers, indicating pure marine conditions within the Helsingborg

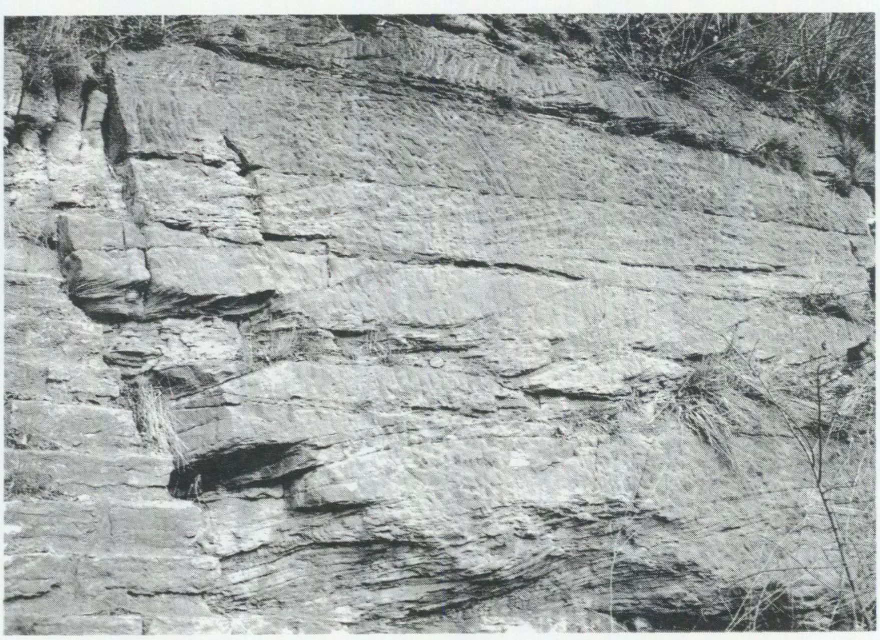


Fig. 28. Trough cross-bedding at Halalid indicating westward sediment transport. Locality A9. Photo: A. Ahlberg.

Member, have been found. That is the Välluf E6 Viaduct Exposure some 7 km ESE of Helsingborg centre. This foraminiferal fauna includes forms known from the Rhaetian-Lower Liassic in Europe (Norling 1972).

LITHOLOGY AND LITHOSTRATIGRAPHY: The Hälsan Gorge outcrop is composed of a 12 m high section of heterolitic, fine-grained sandstone and mudstone with a thin coal-seam (Lindström 1987a, Pieńkowski 1991b). According to Pieńkowski the exposed section should be referred to cycle 4 or 5 *sensu* Troedsson (1951), that is to the Lower Hettangian.

SEDIMENTOLOGY: The sedimentary column exposed at Hälsan commences with flaser and cross-bedded sandstone locally rich in charred rootlets. The sedimentary structures indicate deposition in intertidal to supratidal flats. The flaser bedded sandstone grades upwards into wavy bedded sandstone and mudstone dissected by sandy ebb drainage channels. Synsedimentary dewatering structures are abundant in this part of the section. Towards the top sandstones with wavy bedding grade into mudstones with lenticular bedding rich in ripples and trace fossils (mostly *Planolites*). The entire section reflects the drowning (transgression) of a tidally influenced delta plain due to early sediment compaction and a waning clastic supply (i.e. a typical example of a delta lobe abandonment. See Pieńkowski 1991b).

REMARKS: This locality is situated in a private garden. Permission is required before entering the outcrop.

REFERENCES: Lindström (1987a, 1987b), Norling (1972), Pieńkowski (1991a, 1991b), Troedsson (1951).

A11. LARÖD

OBJECTIVE: Helsingborg Member, Höganäs Formation, Hettangian and Döshult Member, Rya Formation, Lower Sinemurian.

LOCATION: About 8 km N of Helsingborg centre (Fig. 17).

MAP SHEETS: Topography.- 3C Helsingborg SV. Geology.- SGU Ser. Af 149 Berggrundskartan 3C Helsingborg SV (Map of solid rocks).

COORDINATES: Helsingborg Member: 622270/130330, Döshult Member: 622250/620350.

GEOLOGICAL SETTING: At this locality the two units Helsingborg Member and Döshult Member are separated by a fault line with a SW–NE strike. The vertical displacement along the fault is about 100 m, the northern block being downfaulted. A brecciation of the bedrock along the faultline has been observed (Troedsson 1951).

BIOSTRATIGRAPHY AND CHARACTERISTIC FOSSILS: No fossils have been examined from the Döshult sandstone. From the Helsingborg Member Troedsson (1947) described fossil plants referred to *Nilssonia polymorpha* and *Schizoneura hoerensis*.

LITHOLOGY AND LITHOSTRATIGRAPHY: The Döshult Sandstone is exposed north of the fault line at Laröd. It consists of coarse, cross-bedded subarkose and siltstone. South of the fault line lenticular and wavy beds of the Helsingborg Member can be observed beneath the Quaternary cover.

SEDIMENTOLOGY: The Döshult sandstones at Laröd consist of well sorted tabular and trough cross-bedded sandstones. Foreset orientations of individual bedsets commonly show a pattern indicating sediment transport direction from north to south and vice versa, i.e. a pattern of herringbone stratification (Fig. 29). Each bedset was deposited as the lowermost part of a large scale aquatic dune or sandwave, which was partly eroded by the subsequent one. Deposition took place in a nearshore turbulent marine setting due to strong reversing longshore currents, possibly related to tidal effects.

REFERENCES: Hadding (1929), Ledje (1985), Pieńkowski (1991a, 1991b), Sivhed & Wikman (1986), Troedsson (1951).

A12. KULLA GUNNARSTORP COAST CLIFF SECTION

OBJECTIVE: A 155 m long and 2–3 m high section of Upper Hettangian intertidal heterolitic mudstones and channel fill arenites.

LOCATION: About 10 km N of Helsingborg centre near the Helsingborg—Höganäs road (Fig. 17).

MAP SHEETS: Topography.- Helsingborg 3C SV. Geology.- SGU Ser Af 149 Berggrundskartan 3C Helsingborg SV (Map of solid rocks).

COORDINATES: 622415/130230.

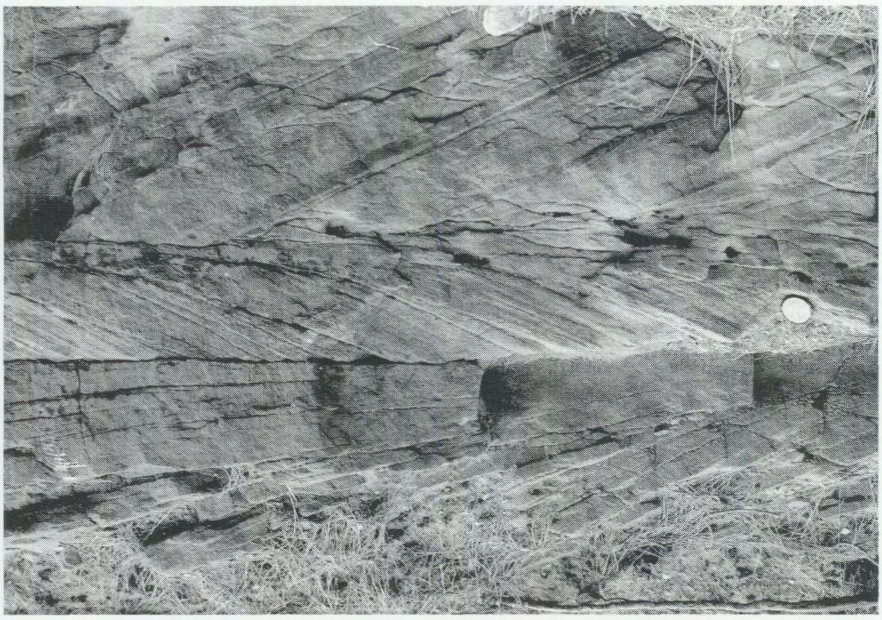


Fig. 29. Herringbone stratification in Sinemurian strata at Laröd. Locality A11. Photo: A. Ahlberg.

GEOLOGICAL SETTING: This locality is situated in the Höganäs Basin and represents the uppermost part of the Helsingborg Member, Höganäs Formation.

BIOSTRATIGRAPHY AND CHARACTERISTIC FOSSILS: Several bivalve taxa have been recorded from the so called *Avicula* Bank and the *Ostrea* Bank. The faunas do not, however, include any index fossils (cf. Lundgren 1881, Troedsson 1951, 1954).

In the cliff section at Kulla Gunnarstorp a diverse invertebrate ichnofauna was described by Frandsen (1977). This fauna includes forms such as *Pelecypodichnus, Diplocraterion, Skolithos, Cylindrichnus, Thalassinoides, Teichichnus, Asterostoma, Phycoides, Planolites,* and *Kouphichnium*. In addition, Pieńkowski (1991b) recognized the ichnotaxon *Rhizocorallium* at this locality.

LITHOLOGY AND LITHOSTRATIGRAPHY: Lenticular and wavy bedded mudstones and sandstones (heterolites) dominate the section. Ripple drift directions indicate bidirectional flow patterns. A low angle disconformity can be seen within the lenticularly bedded mud- and sandstone

Fig. 30. The coast cliff section at Kulla Gunnarstorp. Locality A12. Photo: A. Ahlberg.

sequence. Isolated, 0.1–2.0 m wide sandstone channels, which are indurated by siderite, are incised in the surrounding heterolitic strata.

SEDIMENTOLOGY: The diverse ichnofauna indicates proximity to open marine conditions (Frandsen 1977). He, as well as Pieńkowski (1991b) and the present authors agree that deposition took place on wave agitated intertidal flats. Sand was deposited during low sea level stands in small ebb drainage channels.

DIAGENESIS: The ebb drainage channels were strongly siderite cemented, probably prior to major sediment compaction.

REMARKS: The coastal cliff section can easily be approached from the parking place of the Kulla Gunnarstorp manor-house. Some 100 m south of the manor-house, an east–west oriented gorge can be followed westwards to the shore. This gorge is developed along a vertical fault separating Upper Hettangian from Lower Sinemurian strata. The locality is situated along the shore, some 50 m south of the intersection with the gorge. An outcrop of Sinemurian coarse-grained herringbone cross-bedded arenites, belonging to the Döshult Member of the Rya Formation, can be found along the shore, about 200 m north of the gorge mentioned.

REFERENCES: Bergström & Norling (1986), Frandsen (1977), Lundgren (1881), Norling (1982), Pieńkowski (1991b), Sivhed & Wikman (1986), Troedsson (1951).

A13. DÖSHULT SANDSTONE QUARRY

OBJECTIVE: Type locality for the Döshult sandstone, a bed of the Döshult Member, Rya Formation, Lower Sinemurian.

LOCATION: The quarry is situated in the Höganäs Basin of NW Scania, some 4 km ESE of Viken church (Fig. 17).

MAP SHEETS: Topography.- 3B Höganäs NO/3C Helsingborg NV 1969. Geology.- SGU Ser Af 129 Berggrundskartan 3B Höganäs NO/ 3C Helsingborg NV (Map of solid rocks).

COORDINATES: 622750/130330.

GEOLOGICAL SETTING: The old quarry, long since abandoned, is to be found close to the road and east of the old windmill in the Döshult village. In the vicinity of Döshult, the Döshult Member is distributed along the coast between Lerberget–Viken–Domsten–Kulla Gunnarstorp (grid symbols on topographical maps: 6j–5j–5a), north of Döshult in the Klappe area, and within a narrow trough east of Döshult, framed by slight uplifts with Hettangian deposits. At Domsten (5a) and along the coast at Kulla Gunnarstorp (3C Hg SV: 4a) several exposures of the Döshult sandstone can be found (Fig. 17).

BIOSTRATIGRAPHY AND CHARACTERISTIC FOSSILS: At the Döshult sandstone quarry the only fossils obtained are fragments of silicified wood of little value in stratigraphy. However, other parts of the Döshult Member, including nearby strata of clays and marls, have yielded ammonites indicating that the member corresponds to the *Bucklandi, Semicostatum* and *Turneri* Ammonite Zones of the Lower Sinemurian (Reyment 1959, 1969). The rich faunas of foraminifers and ostracodes support this biostratigraphical dating (Norling 1972, Sivhed 1980). The ammonite, foraminiferal, ostracodal and palynological zonations of the Lower Jurassic in Sweden are given in Fig. 9 (p. 22).

LITHOLOGY AND LITHOSTRATIGRAPHY: In the Döshult sandstone quarry quartz sand and sandstones crop out. They are brownish from iron oxide and well stratified in undisturbed, cross-bedded layers. The grain fraction is fairly coarse with well rounded pebbles, 10–20 mm in diameter, scattered in the sand/sandstone, or concentrated at certain horizons. The Döshult sandstone, established by Troedsson (1951), forms a bed of the Döshult Member. Apart from soft, coarse, cross-bedded sandstones, the Döshult Member includes well lithified, ferruginous sandstones and siltstones, mudstones and marls, the latter to be found in the uppermost part of the member.

REFERENCES: Bölau (1959), Norling (1972, 1982), Norling & Wikman (1990), Reyment (1959, 1969), Sivhed (1980, 1984), Troedsson (1951).

A14. DÖSHULT MARL PIT

OBJECTIVE: Lower Sinemurian, Döshult Member, Rya Formation.

LOCATION: The marl pit is situated in NW Scania, c. 4 km ESE of Viken church (Fig. 17).

MAP SHEETS: Topography.- 3B Höganäs NO/3C Helsingborg NV 1969. Geology.- SGU Ser. Af 129 Berggrundskartan 3B Höganäs NO/3C Helsingborg NV 1980 (Map of solid rocks).

COORDINATES: 622900/130280.

GEOLOGICAL SETTING: This locality is an old marl-pit known since the 19th century (e.g. Lundgren 1881). The marl pit is usually filled with water covering most of the rock sequence. At low water level (usually during the summer), a sequence some 1.7 m in thickness may be seen, including fossiliferous marl and more or less horisontal arenaceous and argillaceous strata.

BIOSTRATIGRAPHY AND CHARACTERISTIC FOSSILS: Lundgren (1881) and Troedsson (1951) described a fairly rich fauna of ammonites, bivalves and other macrofossils from marl pits in the Döshult area. Unfortunately, none of these authors clearly reported where they collected their material. It is obvious, however, that part of their collections came from the present locality (Loc. No. 66 in Troedsson 1951). The marl pit collections include ammonite species such as *Arietites bucklandi, Megarietites meridionalis* and *Arnioceras semicostatum*. The fauna indicates that the marly sequence of the Döshult Member in this area should be referred to the upper subzone of the *Arietites bucklandi* Zone and to the *Arnioceras semicostatum* Zone of the Lower Sinemurian. The ostracode fauna from this locality, studied by Sivhed (1980), includes species such as *Christacythere betzi, Pseudomacrocypris subtriangularis, Polycope cerasia*, and *Ogmoconchella danica*, and indicates the same time interval (Fig. 9).

LITHOLOGY AND LITHOSTRATIGRAPHY: The following sequence can be studied at low water level in the marl pit (preferably from a rubber boat):

0.00–0.40 m	Marlstone light grey, hard with whitish shell fragments.
0.40–0.95 m	Clay, dark grey and shale, blackish, interbedded.
0.95–1.15 m	Shale, dark brown.
1.15–1.35 m	Siltstone, ferruginous, hard, clayish
1.35–1.70 m	Claystone and shale, soft, greyish brown.
Water level	

This sequence belongs to the upper part of the Döshult Member of the Rya Formation. A correlation chart for the chrono-, litho- and biostratigraphical subdivision of the Swedish Lower Jurassic, is given in Fig. 9 (p. 22).

REFERENCES: Bölau (1959), Lundgren (1881), Norling (1972, 1982), Norling & Wikman (1990), Reyment (1959), Sivhed (1980, 1984), Troedsson (1951).

A15. HÖGANÄS MUSEUM

OBJECTIVE: Exhibitions showing the history of coal- and fire-clay mining, pottery and ceramic art.

LOCATION: Höganäs is a small seaside town situated in NW Scania, on the boundary between the Sound (Öresund) and Kattegatt (Fig. 17).

MAP SHEETS: Topography.- 3B Höganäs NO/3C Helsingborg NV. Geology.- SGU Ser Af 129 Berggrundskartan 3B Höganäs NO/3C Helsingborg NV (Map of solid rocks).

REMARKS: For centuries NW Scania has been Sweden's coal and clay mining district. Höganäs is the centre of this district. Today, the coal-mining has almost come to an end, and the fire-clay mining is of minor importance. Still, however, NW Scania is the most well known pottery district in Sweden. In 1992 more than 50 potters, stoneware and ceramic manufacturers were known to have their studios in NW Scania (you can get an address list at Höganäs Museum).

Höganäs Museum, founded in 1924, has an interesting mining section showing the history of coal- and clay-mining, the old equipment used, and a small geological exhibition showing rock specimens and various fossils such as Rhaeto-Jurassic plants and dinosaur footprints. Other sections show the prehistory of NW Scania and permanent exhibitions of ceramics, representative of the district. Every summer new temporary ceramic and art exhibitions are presented. At the museum you will get guides and pamphlets of interest and literature can be bought.

ADDRESS: Polhemsgatan 1, S-263 37 Höganäs. TELEPHONE: 042-341335. OPENING TIMES: March–Dec., Tuesday–Sunday 13.00-17.00 hours.

Fig. 31. Geological map with excursion localities of central and southern Scania (see legend in Fig. 1).

B) EXCURSION LOCALITIES, CENTRAL SCANIA AND THE FYLEDALEN VALLEY

A location map is given in Fig. 31.

B1. DJUPADALSMÖLLA

OBJECTIVE: Jurassic sequence of sandstone, clays and volcanic tuffaceous rocks and debris flows.

LOCATION: Djupadal is located some 6 km northeast of Röstånga on the road to Hallaröd. The volcanic tuff is best studied c. 100 m west of an old bridge in the southern slope of the Rönne River.

MAP SHEETS: Topography.- 3C Helsingborg SE. Geology.- SGU Ser Af 180 Berggrundskartan 3C Helsingborg SE (Map of solid rocks).

COORDINATES: 621250/134910.

GEOLOGICAL SETTING: Scania was subjected to volcanic activities during the Jurassic and the Cretaceous. The volcanism was concentrated to an area in Central Scania and at Brösarp in SE Scania (Figs. 1, 6, 31). It has been possible to locate some 70 volcanoes from air magnetometric data (Bergström 1981). Tuffaceous debris has been found in connection with some of the volcanoes. It flowed down into the surrounding lowland areas. The volcanism also resulted in the formation of basalts (Fig. 34). The tuffaceous rocks at Djupadalsmölla are assigned to the Jurassic with the aid of palynological, palaeomagnetic and K-Ar datings (Tralau 1973; Bylund 1973; Klingspor 1976). As mentioned above, Djupadal is situated in the Rönne River valley. To the west of the river a depression partly filled with Jurassic rocks occurs. A 3 m thick section of Jurassic rocks can be observed beneath the Quaternary cover. It rests on the kaolinized Proterozoic basement. The nearest eroded volcanic neck is named Äskekull, located about 1 km south of Locality B1, Djupadalsmölla (Fig. 31).

BIOSTRATIGRAPHY AND CHARACTERISTIC FOSSILS: The deposits at Djupadalsmölla have yielded frequent plant remains. No other megafossils are recorded. Tralau (1973), determined the age as Toarcian–Aalenian on palynological evidence.

LITHOLOGY AND LITHOSTRATIGRAPHY: The section includes a 3 m thick sequence of Jurassic rocks (Fig. 32). This stratum overlies kaolinized basement consisting of Proterozoic gneiss. The basal 2 m of the sequence include alternating beds of claystone and sandstone with abundant plant remains. The upper 1 m of the Jurassic section consists of greyish green and brownish tuffaceous rocks. The deposit is characterized by a heterogenous mixture of volcanic products, clasts of crystalline rocks, fragments of sedimentary rocks and plant remnants. Volcanic bombs (lapilli) have also been identified (Lidmar-Bergström 1988).

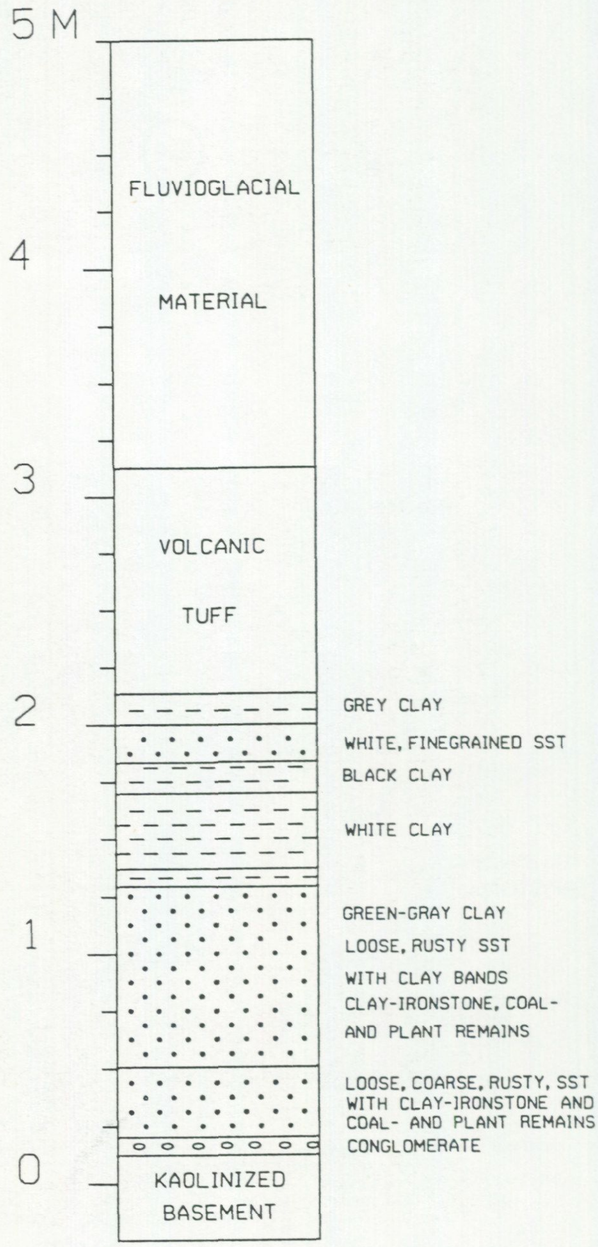


Fig. 32. Lithological column of the sequence exposed at Djupadalsmölla. Locality B1.

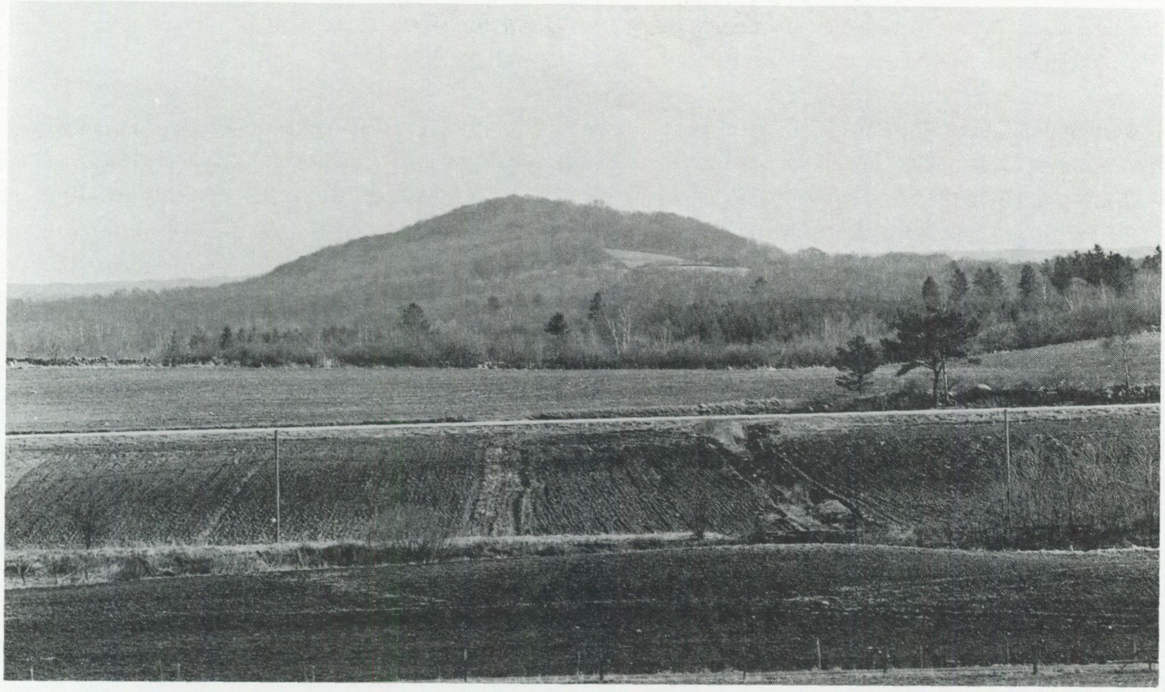


Fig. 33. Eroded volcanic neck at Jällabjär, Central Scania (3CSO6212/1346). Photo: H. Wikman, SGU, Lund.

Fig. 34. Columnar jointing in Mesozoic basalt, Ballran, Häglinge, Central Scania (3DSV620915/137090). Photo: H. Wikman, SGU, Lund.

SEDIMENTOLOGY: The basal part of the sequence was probably deposited in a a freshwater to marshy environment. This interpretation is based on the occurrence of coal, plant remains and alternating layers of clay, sand and ferruginous sediments. The tuffaceous bed was most likely formed as a debris flow, which mixed with plants and sediments during the downhill transport into the depositional area. The flow most likely came from the nearby Äskekull volcano.

REMARKS: Tullberg & Nathorst (1881) were the first to report on a 12 m thick sequence of tuffaceous rocks on the south bank of the Rönne River a few hundred metres west of Djupadalsmölla. Parts of the section are still accessible.

REFERENCES: Bylund (1973), Eichstädt (1883), Grönwall (1935), Klingspor (1976), Lidmar-Bergström (1988), Svedmark (1883), Tralau (1973), Tullberg & Nathorst (1881), Wikman & Sivhed (1993).

B2. KOHOLMA

OBJECTIVE: Jurassic sequence of tuffaceous rocks and debris flows with pyroclastic bombs and lapilli and fossil wood.

LOCATION: At this locality a 0.5 m high section can be seen in a ditch near Koholma, some 3 km WNW of Färingtofta church (Fig. 31).

MAPS SHEETS: Topography.- 3D Kristianstad SV. Geology.- SGU Ser. Af 155 Berggrundskartan 3D Kristianstad SV (Map of solid rocks).

COORDINATES: 621640/135020.

GEOLOGICAL SETTING AND BIOSTRATIGRAPHY: The Koholma tuffaceous rocks are almost of the same character as those at Djupadalsmölla. The precise age is unknown. Based on petrography and plant remains, however, a Jurassic age has been proposed. No other fossils have been found.

LITHOLOGY: The deposits exposed in the ditch consist of greyish green and brownish tuffaceous debris. Large clasts (boulders and pebbles) of crystalline rocks are frequently found, as well as lapilli and plant remnants.

SEDIMENTOLOGY: The deposits were most likely formed as debris flows sliding downhill from a nearby volcano.

REFERENCES: See Djupadalsmölla (B1) and Wikman & Sivhed (1993).

B3. VITTSERÖD SANDSTONE QUARRIES

(Pågagraven, Lundagraven, Storegraven, Smågravarna, Bögerup Quarry, Rävaklint Quarry, and Rugerup Quarry. See Fig. 31.)

OBJECTIVE: Small exposures of the Höör Sandstone, Rhaeto-Hettangian arenites.

LOCATION: The Vittseröd sandstone quarries are situated in Central Scania, about 9 km NW of Höör and 1.5 km east of Stockamöllan (Fig. 31).

MAP SHEETS: Topography.- 3C Helsingborg SO. Geology.- SGU Ser Af 180 Berggrundskartan 3C Helsingborg SO (Map of solid rocks).

COORDINATES: 620530/134990.

GEOLOGICAL SETTING: The Höör Sandstone lies directly on basement rocks, covering an undulating surface that formed the landscape at the end of the Triassic. The sandstone cover is now in the process of being removed by erosion, revealing a relief which is essentially unchanged from the Triassic (Lidmar-Bergström *et al.* 1991). Traditionally, the Höör Sandstone was divided into the basal "millstone" (Stanstorp Member) and the superimposed "building-stone" (Vittseröd Member). Millstones were quarried in the Höör area during the 17th to 19th centuries, whereas building-stones have been utilized from the 11th century and onwards (see p. 30).

BIOSTRATIGRAPHY AND CHARACTERISTIC FOSSILS: Nathorst (1880) studied the macroflora of the Höör Sandstone and Lundgren (1881) established a bivalve zonation for this unit. Troedsson (1940) modified the biostratigraphy and proposed the stratigraphy given in Fig. 8, p. 19.

Today, exposures of the Höör Sandstone are poor in determinable animal and plant fossils, though impressions of fossil wood are fairly common. The Höör Sandstone is correlated stratigraphically with strata of the Rhaeto-Hettangian transition of the Höganäs Formation in NW Scania (Troedsson 1940, 1951).

LITHOLOGY AND LITHOSTRATIGRAPHY: The Höör Sandstone consists of arkoses, subarkoses, quartz arenites and wackes. Scattered conglomerates and rare muddy layers also occur in the sequence. The principal framework grains are quartz and K-feldspar and the most common

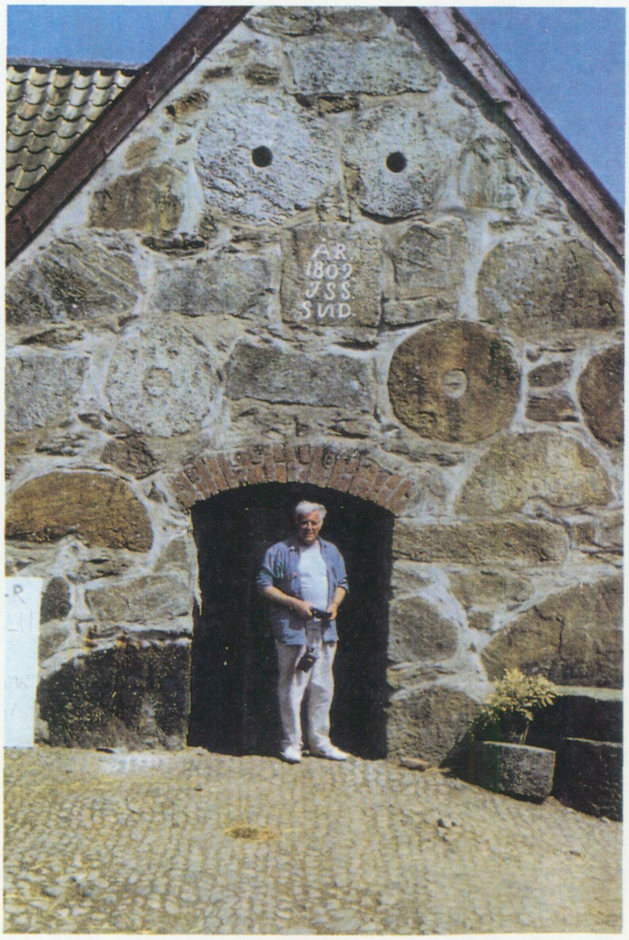


Fig. 35. The senior author at Vittseröd manor-house. Note the Höör Sandstone millstones in the wall. Near Locality B3. Photo: A. Ahlberg.

heavy minerals are ilmenite, titanite and zircon. The framework grain mineralogy and textures indicate a close affinity to the underlying and adjacent gneisses. The millstones and building-stones were classified by Warnock (1983) as a coarse-grained arkose/subarkose, and a fine-grained quartz arenite, respectively.

SEDIMENTOLOGY: Most outcrops of the Höör Sandstone in the Vittseröd area are too small to allow detailed facies analysis. In the Rävaklint and Bögerup quarries arkoses of the Stanstorp Member are well exposed. An alluvial depositional environment may be proposed for the Stanstorp Member because of the abundance of large coal particles (pieces of terrestrial plants), the highly immature detrital mineralogy and trough cross bedding.

Quartz arenites and subarkoses of the Vittseröd Member can be studied in several minor sections in the Vittseröd area, viz. in the Lunda, Påga and Store Quarries, and in the Rugerup Quarry 2.3 km north of Vittseröd. Based on pelecypod finds (Lundgren 1881), herringbone cross-bedding and indications of strong sediment reworking (mineralogical and textural), this member may be interpreted as a nearshore marine deposit (Pieńkowski in ms).

DIAGENESIS: The diagenesis of the Höör Sandstone has recently been investigated by Ahlberg & Goldstein (unpublished data). Their detailed petrographical analyses indicate that initially permeable parts of the Höör Sandstone were strongly indurated by quartz prior to any major sediment compaction. Dissolved silica was presumably derived from extraformational sources. Vitrinite reflectance data and fluid inclusion analysis of quartz indicate that repeated events of quartz cementation were triggered due to flushing of hot brines at temperatures ranging from 90° to 200°C. Middle Jurassic volcanic activities in Central Scania probably induced the anomalous heat flows.

REMARKS: The Höör Sandstone in the Vittseröd area was quarried for building-stone during early medieval times. The cathedral of Lund (Fig. 16) was built with material taken from the Lundagraven, Pågagraven and Smågravarna pits some 900 years ago (For further reading about building-stones, see p. 30).

REFERENCES: Lundgren (1881), Nathorst (1880b), Sivhed (1984), Troedsson (1940), Warnock (1983), Wikman & Sivhed (1993b).

B4. STANSTORPSGRAVEN

(One of several quarries in the Stenskogen–Höör area)

OBJECTIVE: A section of the Höör Sandstone (Rhaeto–Liassic arenites).

LOCATION: 1 km SW of Höör west of the Orup Hospital (Fig. 31).

MAP SHEETS: Topography.- 3D Kristanstad SV. Geology.- SGU Ser Af 155 Berggrundskartan 3D Kristianstad SV (Map of solid rocks).

COORDINATES: 620060/135668

GEOLOGICAL SETTING: The quarried sandstones in the Stenskogen area at Höör are of the same age as those in the Vittseröd area. For data on the geological setting and biostratigraphy of the Höör Sandstone, see Locality B3 (p. 52).

LITHOLOGY AND LITHOSTRATIGRAPHY: A 9 m thick sequence of the Höör Sandstone is exposed at Stanstorpsgraven. The lowermost 1 m is dominated by arkoses of the millstone unit. This layer is overlain by a thin, plastic, coaly mud layer, representing the transition to the building-stone. In the basal part of the building-stone, a storm-bed (tempestite) has been observed. The building-stone is about 7 m thick and consists of well sorted fine-grained quartz arenites and subarkoses, as in the Vittseröd area.

REMARKS: The sandstones quarried in the Stenskogen/Höör area were utilized in the same way as the ones described from the Vittseröd area (B3). Stanstorpsgraven is owned by the Swedish State Church. In recent years, the quarry has delivered small amounts of building material for restauration of the Lund Cathedral. As to sedimentology and diagenesis see B3.

REFERENCES: As for Locality B3 (p. 52) and Wikman & Sivhed (1993a).

B5. ERIKSDAL

At Eriksdal the most extensive exposure of Jurassic strata in Sweden occurs. It is recommended to start a visit in the Kurremölla valley, then to continue into the Fyleverken Sand Pit upwards through the stratigraphical succession. It is not recommendable to study the Fyledal Clay during the wet season when the clays are watersoaked and prone to flow.

OBJECTIVE: Röddinge formation, Lower Jurassic; Fuglunda and Glass Sand Members, Mariedal formation, Middle Jurassic; Fyledal Clay and Vitabäck Clays Members, Annero Formation, Upper Jurassic - Lower Cretaceous.

LOCATION: Eriksdal is situated 20 km north of the town of Ystad in the northeastern part of the Fyledalen Valley, Vomb Trough (Fig. 31).

MAP SHEETS: Topography.- 2D Tomelilla SV. Geology.- SGU Ser Af 142 Berggrundskartan 2D Tomelilla SV (Map of solid rocks).

COORDINATES: 137325/616360.

GEOLOGICAL SETTING: Eriksdal is located at the NE border of the Vomb Trough, which is an asymmetric graben, approximately 80 km in length, and with a width ranging from 7 km in the northern part to 11 km in the south. The Eriksdal area and the eastern border of the Vomb Trough is characterized by a rather complex tectonic evolution along the western boundary of a plateau with Lower Palaeozoic rocks at the surface. A granitic block, known as the Romeleåsen Horst, separates the Vomb Trough from the Danish Subbasin in the southwest. To the south the trough extends offshore from Scania. The bedrock surface in the trough is mainly composed by argillaceous and arenaceous limestones, siltstones and sandstones of Late Cretaceous age (Campanian-Maastrichtian).

The Vomb Trough (Fig. 4) is deepest along the NE border. There, up to 1200 m of Upper Cretaceous deposits rest on a thin and incomplete Jurassic sequence, which in turn overlies the Precambrian crystalline basement. Thick Jurassic strata crop out between Eriksdal and Tosterup (Fig. 37) within a narrow rim along the Fyledalen Fault Zone.

The exposed Jurassic strata belong to a 400–600 m thick sequence deposited in a former graben NE of the Fyledalen Fault Zone. The approximately 50 m thick sequence (Bathonian and Oxfordian–Tithonian strata) found below the thick Cretaceous cover in the central parts of the Vomb Trough was deposited on a Jurassic high (horst).

Tectonic inversion movements in Cretaceous times resulted in an uplift of the former graben NE of the Fyledalen Fault Zone and subduction of the Vomb Trough. A thin rim of strata belonging to the former graben was downfaulted and inverted by fault movements in the Fyledalen Fault Zone (Norling & Bergström 1987).

The Vomb Trough is affected by swarms of faults mainly trending NW–SE, NE–SW, and E–W. These tectonic lineaments are believed to have been repeatedly rejuvenated throughout the Mesozoic, at least until early Late Cretaceous time (Kimmerian to Subhercynian movements). The tectonic events have resulted in the formation of a graben structure (the Vomb Trough), which is subdivided into local block units. These blocks are either uplifted as the Herrestad high in the southern part of the graben, or subsided as the Köpingsberg block. The deepest part of the Vomb Trough is situated within this block.

The present shape of the Vomb Trough is the result from these inversion movements and Late Cretaceous compressional deformation.

The 400–600 m thick Jurassic strata at Eriksdal are more or less vertically tilted, or even slightly overthrusted as an effect of the tectonic evolution of the area (cf. cross-section A–B in Fig. 37B). The strata strike on average N40° W and dip 80° NE.

At Eriksdal four main lithostratigraphical units are exposed (Fig. 36). Lower Jurassic strata (Röddinge formation) outcrop in the Kurremölla Valley.

In the northeastern and central parts of the Fyleverken sand pit (Fig. 38), the Fuglunda and Glass Sand Members (Mariedal formation) of the Middle Jurassic are exposed

Chronostratigraphy			Formation	Member
JURASSIC	Upper	Tithonian	Annero Formation	Vitabäck Clays
		Kimmeridgian		Nytorp Sand
		Oxfordian		Fyledal Clay
	Middle	Callovian	(hatched)	(hatched)
		Bathonian	Mariedal formation	Glass Sand
		Bajocian		Fuglunda M.
		Aalenian	? Röddinge formation	No defined members
	Lower	Toarcian		
		Pliensbachian		
		Sinemurian	?	
		Hettangian	(hatched)	(hatched)

Fig. 36. Jurassic stratigraphy of Eriksdal.

and in the southwestern part the Upper Jurassic Fyledal Clay. Further to the southwest, Upper Jurassic–Cretaceous transitional beds, the Vitabäck Clays, are found directly beneath a thin cover of Quaternary deposits (Fig. 36).

The occurrence of Rhaetian sediments in the area is poorly known. However, samples from Rödalsberg and Munka Tågarp, as well as the Kullemölla core drilling, have indicated a Rhaetian age on the basis of palaeobotanical and palynological analyses (Möller & Halle 1913, Guy-Ohlson 1982). The outcropping sediments at Eriksdal range from the Sinemurian to the Tithonian with a known stratigraphical gap for the Callovian–Oxfordian.

BIOSTRATIGRAPHY AND CHARACTERISTIC FOSSILS: According to Moberg (1888) and Reyment (1959), the basal parts of the limonitic and sideritic sandstone sequences in the Kurremölla Valley have yielded a few ammonites indicating a Late Sinemurian to Pliensbachian age (*Oxynoticeras oxynotum* and *Uptonia jamesoni* Zones). Today, the ammonite-bearing beds are poorly exposed. The lack of fossils in the remaining upper part of the sequence has led to uncertainties as to the biostratigraphical zonation. On lithostratigraphical grounds, however, the exposed sequence in the Kurremölla Valley has been given an alleged age ranging from Sinemurian to Aalenian (Norling 1972; Bergström *et al.* 1982).

The Fuglunda Member (the name coined by Sivhed 1984) is of Bajocian age according to palaeobotanical and palynological evidence (Tralau 1966, 1968). The plant fossils are found mainly in claystones in between the coal-seams in the Fyleverken sand pit. The plant fossil assemblage was named "the Kurremölla Flora" by Möller & Halle (1913).

The Glass Sand overlies the Fuglunda Member and was dated to the Bathonian by Tralau (1968). Between the Glass Sand and the Fyledal Clay there is a major hiatus including parts of the Bathonian, the Callovian–Oxfordian, and parts of the Kimmeridgian. A Kimmeridgian age is given the Fyledal Clay on the basis of ostracodes (Christensen 1968). Also bivalves occur, as well as arenaceous foraminifers, calcareous algae and plant fragments of unknown affinity.

The Vitabäck Clays, which are known from temporary excavations SW of the sand pit, contain a fairly rich bivalve fauna (Hägg 1940, Ekström 1985). A well preserved palynoflora indicates a Tithonian–Berriasian age. The Vitabäck Clays thus span the Jurassic-Cretaceous boundary (Erlström *et al.* 1991, 1993). The Nytorp Sand of the Upper Jurassic is known only from older pits and excavations. Norling (1972), who coined the name Nytorp Sand, determined the age of this unit as Kimmeridgian/ Tithonian.

LITHOLOGY AND LITHOSTRATIGRAPHY:

Röddinge formation.- The informal name Röddinge formation is introduced in this contribution. The ferruginous sandstones, representing this unit, outcrop in the Kurremölla Valley. They are assigned a Sinemurian–Aalenian age and are composed of limonitic, chamositic and sideritic sandstones. Oolitic chamosites are fairly frequent in the sequence. The exposed deposits are weathered and consequently characterized by reddish brown and yellow coloured limonitic strata. Unweathered deposits, known from borings, are greyish dark green and composed of chamositic and sideritic varieties. The iron content varies between 8% and 10% in the limonitic sandstones, while the oolitic ones may contain up to 20% (Hadding 1933). The oolitic chamosite is calcitic. The less frequent calcitic variety is found mainly in the basal part of the Röddinge formation. The grains in the chamosite oolite are around 0.3 mm in diameter and ellipsoid in shape. The core is usually composed of a quartz grain, occasionally of a heavy mineral grain, surrounded by concentric layers of chamosite.

The chamositic and sideritic sandstones, which dominate the interval, are composed of a fine to medium-grained sub-quartzite, moderately consolidated by a chamositic or sideritic cement. The sandstones have a very small content of heavy minerals and feldspars. Iron ooids are fairly abundant. An approximately 1.7 m thick bed of siderite oolite with an iron content of up to 35% is found in the upper part of the ferruginous sandstone unit at Kurremölla. This bed was of major interest for mining during the 1930's (p. 31). Today, only a small adit remains as a reminder of the iron prospecting.

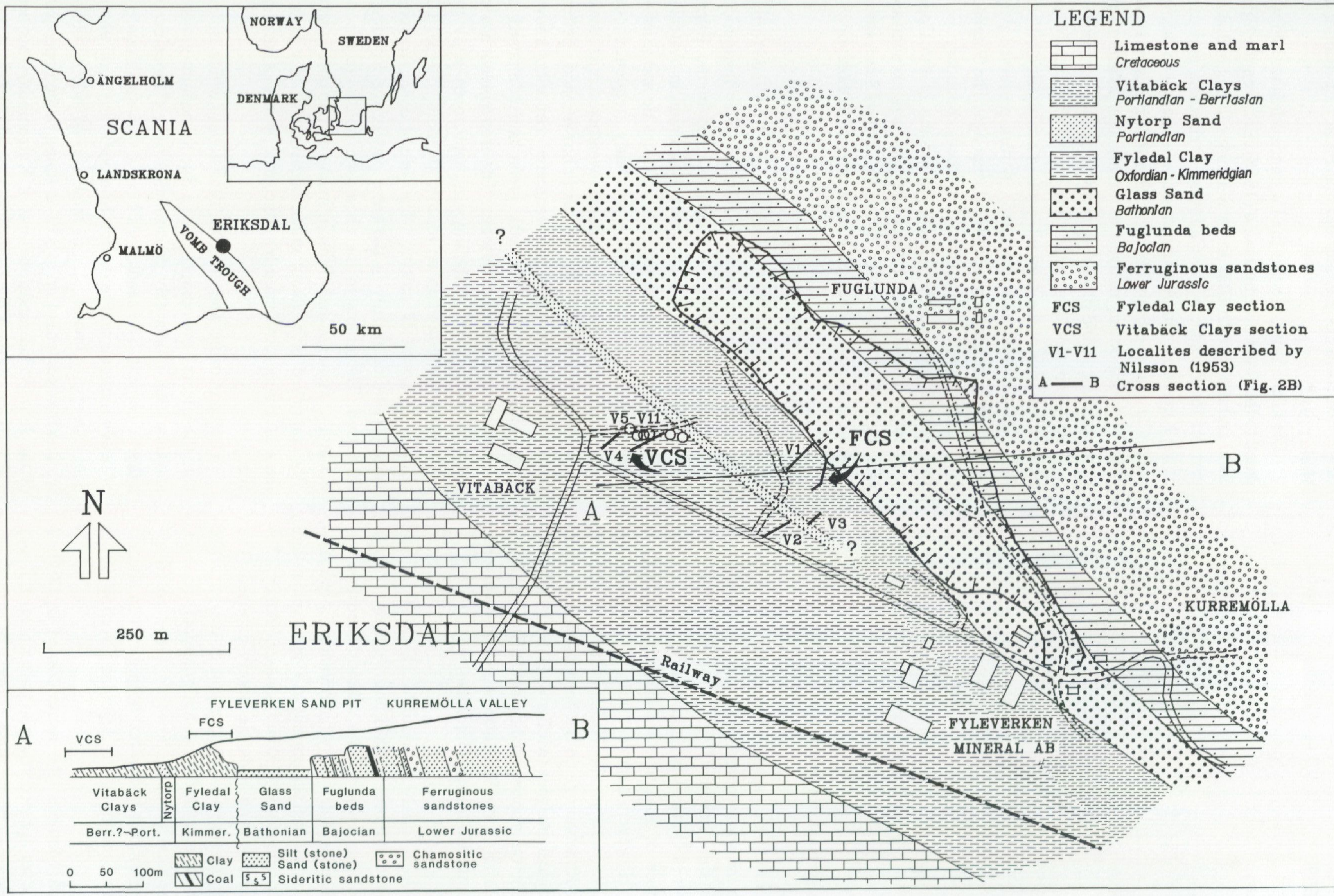


Fig. 37. Geological map of the Eriksdal area (locality B5) and schematic cross section (A–B). Marked sections and localities on the map are described in Erlström *et al.* 1991.

Conglomerates are fairly abundant in the ferruginous sandstone interval. They occur in up to 1 m thick beds dominated by intraclasts of chamositic and sideritic sandstone, 2–5 cm in thickness.

Fuglunda Member (Mariedal formation).- This lithostratigraphical unit consists of a 100 m thick sequence of repeated cycles of sand, clay and coal. The lower part is characterized by thin cycles of sand, clay and coal. The upper 40 m thick part is composed of 5–6 m thick cycles. It is overlain by the Glass Sand.

The fine-grained, heterolitic claystone beds of the Fuglunda Member are characterized by grey to blackish grey kaolinitic claystones, generally succeeded by fine-grained bioturbated sandstones, topped by a unit of siltstones with rootlets and a coal-seam. The thicker sandstone beds in the Fuglunda Member are cross-bedded, indicating a palaeocurrent trending E to ENE.

Glass Sand Member (Mariedal formation).- The Glass Sand unit is dominated by white quartz sand with few percent of kaolinite matrix. The basal part of the unit contains slightly less pure and greyish varieties. Between the upper and lower part a brownish black sand occurs, which contains fine humic and coal-dust material in its matrix. The Glass Sand is dominated by cross-bedded, medium-grained sand, interbedded with fine-grained flaser-bedded layers with *Diplocraterion* near the top. The upper part of the Glass Sand consists of a pure white quartz sand with occasional streaks and bandings of ferruginous concretions and heavy minerals. The sand is quarried by the Fyleverken Company for its unique content of silica (> 99%).

Fyledal Clay Member (Annero Formation).- The exposed part of the Fyledal Clay is approximately ≥10 m thick. The deposits are dominated by alternating greenish and greyish black, argillaceous beds with thicknesses between 0.5 m and 2 m. The contact towards the underlying Glass Sand can be seen in the south-west corner of the Fyleverken Sand Pit. Laterally impersistent wedge-shaped beds of fine-grained sideritic sandstones occur mainly in the basal part of the unit. Carbonate nodular beds occur some 40 m above the contact to the Glass Sand. Rootlet horizons are relatively frequent. A more comprehensive treatment of the Fyledal Clay lithology is presented by Erlström *et al.* (1991).

Vitabäck Clays Member (Annero Formation).- The deposits referred to as the Vitabäck Clays are known from ditch sections. Today, this unit is not exposed in the Eriksdal area. The Vitabäck Clays are composed of a heterogeneous sequence of differently coloured and more or less argillaceous beds. When compared with the Fyledal Clay, however, the Vitabäck Clays show a higher frequency of silty and sandy beds. The unit includes several pedogenic horizons (palaeosols). The petrography and biostratigraphy of the Vitabäck Clays, which span the Jurassic-Cretaceous boundary, were recently treated by Erlström *et al.* (1991).

DEPOSITIONAL ENVIRONMENT:

Röddinge formation.- This unit has so far not been thoroughly investigated as to its depositional environment. Most likely, the coarse-grained nature of the Röddinge strata is linked to a rapid erosion of a tectonically active hinterland. Most likely the sediments were partly deposited in shallow water, which is indicated by the many oolite hori-

Fig. 38. The Fyleverken Sand Pit at Eriksdal. View to the NW. Photo: M. Erlström.

zons. The well sorted sandstones indicate intensive reworking of the strata. The marine influence is evident because of the occasional calcareous beds and finds of ammonites and other marine organisms, such as crinoids (Moberg 1888; Hadding 1933). Primary siderites are generally found in lacustrine deposits. Chamosites are in contrary formed in marine sediments. These facts lead us to the conclusion that major parts of the sediments were deposited on a restricted marine shallow shelf with high energy conditions alternating with coastal lake and near-shore deposition. One possible explanation for the occurrence of sideritic deposits could be the existence of extensive sub-aerial exposure of chamositic deposits and lateritic pedogenic processes in a warm and humid climate (Nilsson 1992).

Fuglunda Member (Mariedal formation).- The frequent cyclicity, the marine intercalations, heterolitic sediments, *Diplocraterion* structures, rootlets, and numerous plant remnants all indicate a deltaic depositional environment in a humid climate. The Fuglunda Member was subdivided into 13 depositional cycles by Rolle *et al.* (1979). The cycles are composed of heterolitic sediments deposited in interdistributary bays, succeeded by sandstone and siltstone beds from prograding distributary tidal channels. The cycles are generally topped by rootlets and coal formed on levees and in delta plain settings. The occurrence of *Diplocraterion* suggests deposition in a beach foreshore environment at the delta front. The subsidence of the depositional area was more or less of the same rate as the deposition, which promoted a cyclic pattern in the Fuglunda Member.

The Glass Sand Member (Mariedal formation).- This unit was formed during high energy conditions; most likely in extensive tidal channels, delta front complexes and migrating sand bars. Interbeds of heterolites indicate deposition in small lagoons. The sandstone with *Diplocraterion* was probably deposited in a beach-foreshore area. The delta was probably wave dominated and the depositional environment affected by intense reworking. Beach deposits have been recorded from the uppermost part of the unit immediately beneath the Fyledal Clay. Palaeocurrent measurements indicate a tripolar pattern, ENE and WSW, perpendicular to the Tornquist Zone, and SSE, parallel to the presumed coast-line (Rolle *et al.* 1979).

Fyledal Clay (Annero Formation).- Occurrence of rootlet beds, freshwater and lacustrine-brackish-marine fossils (ostracodes, arenaceous and calcareous foraminifers, calcareous algae etc.), caliche nodules, gypsum and organic rich beds, verify deposition in shallow lakes, lagoons and swamps (mangrooves) within a low relief coastal marginal environment, i.e. coastal plain. There were restricted marine influences during episodes of local subsidence and compaction of areas, which subsequently were submerged. Shallow, temporary brackish lagoons were developed. Other marine influences are found as wash-over fan deposits of sand with marine biota. Shallow lakes most likely constituted an important element in the depositional setting. Anoxic bottom conditions in quiet water resulted in blackish, organic rich clays and occasional shell debris accumulation. Carbonate and gypsum occurrences verify that the lakes were subjected to evaporation which led to saturation and subsequent precipitation. The intervening areas between the lakes and lagoons consist to a large extent of wet swamps with deposition of clays and silts. Rootlet horizons in connection with blackish claystones verify the occurrence of vegetated areas. Reddish Fe-oxyhydroxides and siderite in the section indicate occasional subaerial exposure and pedogenic processes. The overall uniformity of the Fyledal Clay indicates a continuous subsidence of the depositional area which led to a preservation of a stable environment during much of the Oxfordian–Kimmeridgian times (Erlström *et al.* 1991).

Vitabäck Clays (Annero Formation).- The depositional environment of the Vitabäck Clays is interpreted to show great similarities to that of the Fyledal Clay. The Vitabäck sediments, however, are more varied and slightly richer in coarse clastic material. The fossil fauna and flora obtained indicate a depositional environment characteristic of marginal facies. Most of the Vitabäck Clays were deposited in extended coastal plains which were dominated by environments influenced by freshwater and brackish conditions. Lacustrine conditions with marine influences are indicated by palynomorphs (e.g. *Botryococcus*). Green and blackish organic-rich clays were deposited together with scattered silt lenses during mostly quiet water conditions. Temporarily increased influence from small rivers is verified by the infill sequences of the coastal lagoons. Lagoonal or restricted brackish-marine influences are indicated by certain bivalve records. Abundance of *Botryococcus* verifies that a quiet lacustrine environment frequently prevailed during deposition of the Vitabäck Clays. Numerous plant fragments and rootlet horizons indicate deposition in poorly drained swamps. Occurrence of iron-rich beds indicates occasional subaerial exposure. Pedogenic processes are shown by the presence of palaeosols (Erlström *et al.* 1991).

REFERENCES: Bergström *et al.* (1982); Chatziemmanouil (1983); Christensen (1968); Ekström (1985); Erdmann (1887); Erlström *et al.* (1991, 1993); Guy-Ohlson (1982); Guy-Ohlson & Norling (1988, 1993); Hadding (1929, 1933); Hägg (1940); Moberg (1888); Möller & Halle (1913); Nilsson 1992); Norling (1972); Norling in

Bergström *et al.* (1982); Norling & Bergström (1987); Reyment (1959); Rolle *et al.* (1979); Sivhed (1984); Tralau (1966, 1968).

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Plate I

Photomicrographs of Norian–Hettangian alluvial-deltaic rocks in Scania. (Photo: A. Ahlberg.)

a: Typical arkose of the Kågeröd Formation. Note abundant feldspars (F), early diagenetic haematite cement (Hc) and later poikilotopic calcite cement (Cc). Q=quartz grain. Crossed polars, scale bar is 0.1 mm.

b: Porous (p) quartz arenite of the Höganäs Formation. Note the scarcity of feldspars (F) and predominance of quartz grains (Q). The presence of organic matter (o) is characteristic of Rhaetian–Hettangian rocks in Scania. Without polars, scale bar is 0.1 mm.

c: Quartz cemented arenite of the Höör Sandstone. Note the original pores, now completely filled with quartz cement (Qc), which surround the detrital quartz grains (Qg). Crossed polars, scale bar is 0.1 mm.

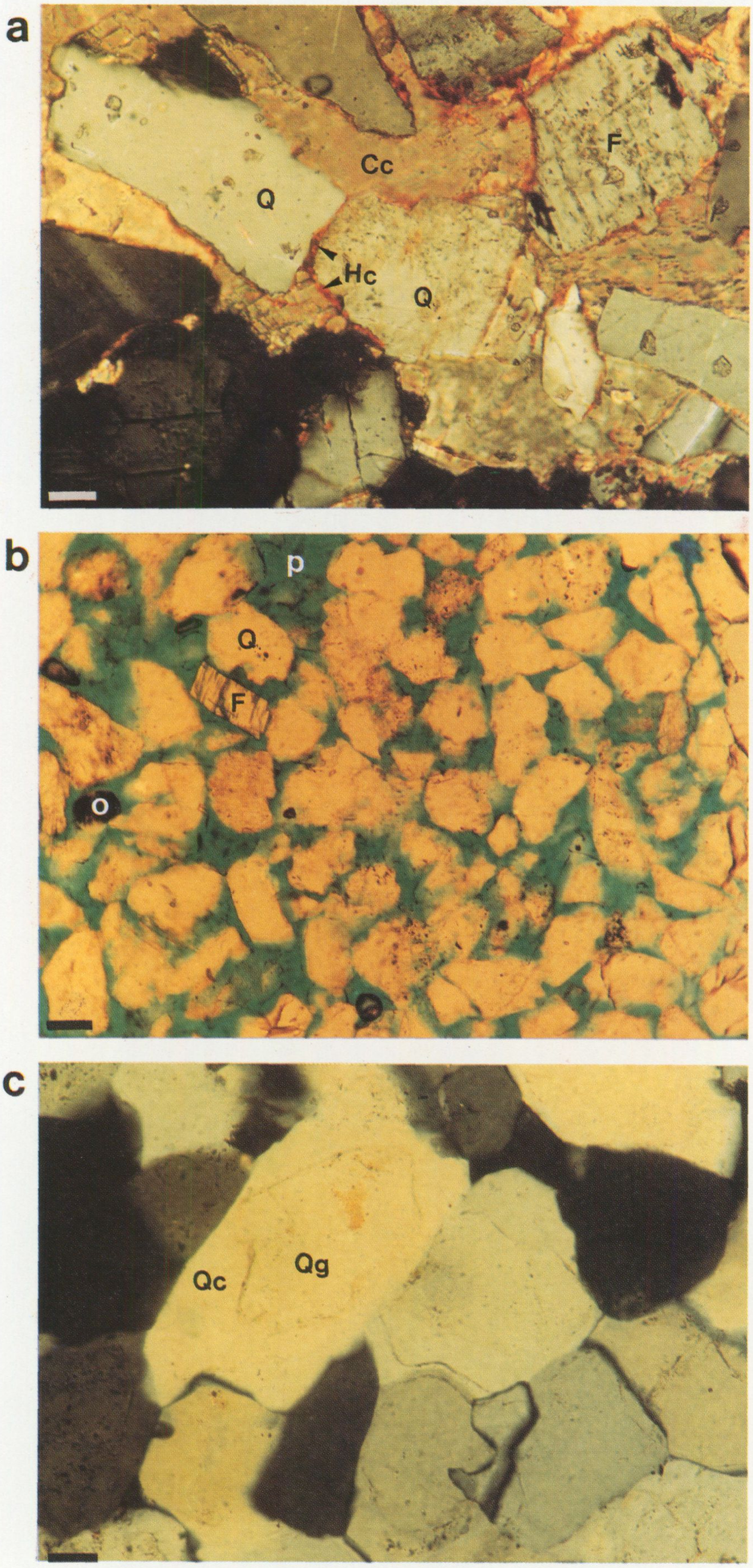

a
Cc
F
Q
Hc
Q
b
p
Q
F
o
c
Qc
Qg

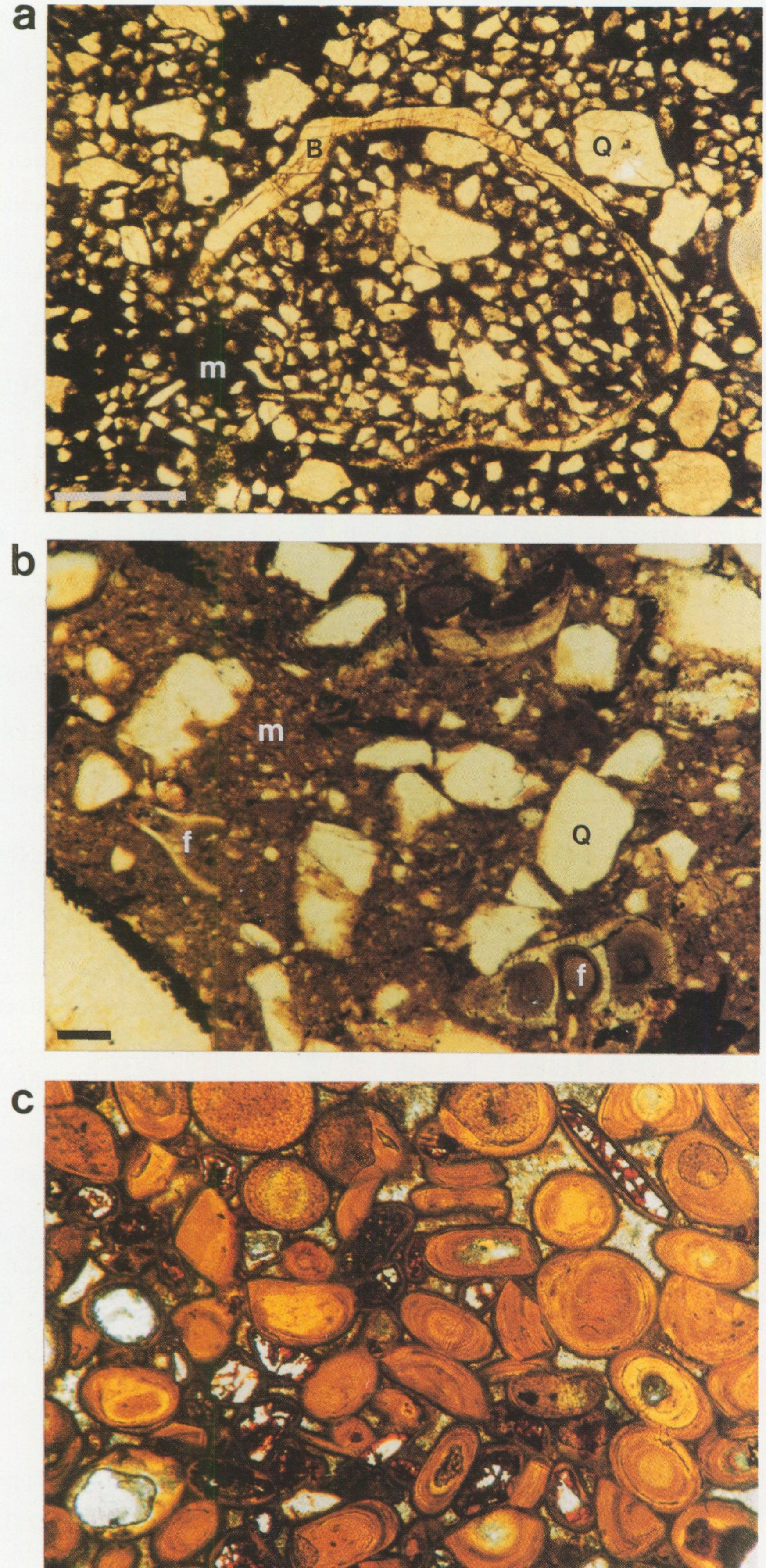
Plate II

Photomicrographs of Sinemurian–Toarcian marine rocks in Scania. (Photo: A. Ahlberg.)

a: Bivalve in sandy micrite of the Katslösa Member, Rya Formation. Without polars, scale bar is 1 mm. Q=quartz grain, m=micrite, B=calcite shell of bivalve.

b: Foraminifers (f) in sandy micrite of the Rydebäck Member, Rya Formation. No polars, scale bar is 0.1 mm.

c: Iron ooides; oolite of the Rydebäck Member, Rya Formation. No polars, scale bar is 0.5 mm.


a
B
Q
m
b
m
f
Q
f
c

APPENDIX I

LIST OF DIAGNOSTIC FORAMINIFERS

***Astacolus semireticulata* Zone (U. Hettangian – L. Sinemurian)**

Astacolus semireticulata NORLING (U. Helsingborg Member— Döshult Member).
Citharina inaequistriata (TERQUEM) (Döshult and Pankarp Members)
Ichthyolaria intercostata (KRISTAN-TOLLMANN) (U. Helsingborg Member)
Neobulimina sp. No. 2 BANG (Döshult Member)
Pseudonodosaria plumiricostata (KRISTAN-TOLLMANN) (Helsingborg Member)
Tetrataxis inflata KRISTAN (U. Helsingborg Member)
Trochammina gryci TAPPAN (Döshult and Pankarp Members)
Vaginulinopsis exarata (TERQUEM) (Döshult Member)

***Marginulina spinata spinata* Zone (U. Sinemurian – L. Pliensbachian)**

Astacolus denticula carinata (FRANKE) (Katslösa – L. Ryde-bäck Members)
Citharina inaequistriata (TERQUEM) (Döshult and Pankarp Members)
Ichthyolaria frankei (BRAND) (Katslösa and L. Rydebäck Members)
Ichthyolaria mesoliassica (BRAND) (Katslösa Member)
Marginulina spinata spinata TERQUEM (U. Pankarp Member – Katslösa Member)
Trochammina gryci TAPPAN (Döshult and Pankarp Members)
Vaginulina listi (BORNEMANN) (U. Döshult – Pankarp-Katslösa Members)

***Saracenaria sublaevis* Zone (Upper Pliensbachian)**

Astacolus denticula carinata (FRANKE) (Katslösa – L. Rydebäck Members)
Brizalina liassica (TERQUEM) amalthaea (BRAND) (top Katlösa Member – basal Rydebäck Member)
Ichthyolaria frankei (BRAND) (U. Katslösa Member – L. Rydebäck Member)
Marginulina spinata interrupta TERQUEM (L. Rydebäck Member)
Nodosaria quadrilatera (TERQUEM) (Katslösa Member – L. Rydebäck Member)
Saracenaria sublaevis (FRANKE) (L. Rydebäck Member)

***Citharina clathrata* Zone (Toarcian – Aalenian)**

Anomalina liassica ISSLER (Rydebäck Member – basal Fuglunda Member)
Citharina clathrata (TERQUEM) (U. Rydebäck Member – basal Fuglunda Member)
Marginulina reversa (BLAKE) (Katslösa Member – Rydebäck Member)
Palmula deslongschampsi (TERQUEM) (Rydebäck Member)
Saracenaria trigona (TERQUEM) (Upper Rydebäck Member)
Tristix liasina (BERTHELIN) (U. Katslösa Member – Rydebäck Member – basal Fuglunda Member)

***Epistomina parastelligera* & *Reinholdella dreheri* Zone (Aalenian–Bajocian)**

Epistomina conica TERQUEM (Fuglunda Member, Fortuna Marl)
Epistomina parastelligera (HOFKER) (Fuglunda Member, Fortuna Marl, Fyledal Clay)
Reinholdella dreheri (BARTENSTEIN) (Rydebäck Member – Fuglunda Member)
Reinholdella media (KAPTERENKO-CHERNOUSOVA) (Fuglunda Member)
Trochammina sablei TAPPAN (Fuglunda Member)

***Saracenaria oxfordiana* & *Saracenaria phaedra* Zone (top Bathonian – Lower Oxfordian)**

Citharina macilenta (TERQUEM) (Fortuna Marl)
Epistomina callovica KAPTERENKO-CHERNOUSOVA (Fortuna Marl)
Epistomina mosquensis UHLIG (Fortuna Marl)
Frondicularia nikitini UHLIG (Fortuna Marl)
Lenticulina quenstedti (GÜMBEL) (Fortuna Marl)
Lenticulina tricarinella (REUSS) (Fortuna Marl)
Marginulina batrakiensis (MYATLIUK) (Fortuna Marl)
Marginulina prima D'ORBIGNY *fortunensis* NORLING (Fortuna Marl)
Saracenaria cornucopiae (SCHWAGER) (Fortuna Marl)
Saracenaria oxfordiana TAPPAN (Fortuna Marl)
Saracenaria phaedra TAPPAN (Fortuna Marl)

***Reophax suprajurassica* Zone (Upper Oxfordian)**

Haplophragmoides haeusleri LLOYD (Fyledal Clay)
Haplophragmoides canui CUSHMAN (Fyledal Clay)

Lenticulina fraasi (SCHWAGER) (Fortuna Marl, Fyledal Clay)
Reophax sterkii HAEUSLER (Fyledal Clay)
Reophax suprajurassica HAEUSLER (Fortuna Marl, Fyledal Clay)

Valvulina meentzeni Zone (Kimmeridgian)

Ammobaculites coprolitiformis (SCHWAGER) (Fyledal Clay)
Ammobaculites laevigatus LOZO (Fyledal Clay)
Ammobaculites subaequalis MYATLIUK (Fyledal Clay)
Astacolus anceps (TERQUEM) (Fortuna Marl, Fyledal Clay)
Astacolus cordiformis (TERQUEM) (Fyledal Clay)
Epistomina parastelligera (HOFKER) (Fuglunda M., Fortuna Marl, Fyledal Clay)
Reophax helvetica HAEUSLER (Fyledal Clay)
Textularia jurassica GÜMBEL (Fyledal Clay)
Trochammina globigerinoides HAEUSLER (Fyledal Clay)
Valvulina meentzeni KLINGLER (Fyledal Clay)

Lenticulina muendensis Zone (Tithonian)

Lenticulina muendensis MARTIN (Vitabäck Clays)
Pseudocyclammina sp. (specimens showing close affinity to forms recorded from the "Gigasschichten" and "Eimsbäckhäuser Plattenkalk" in W. Germany (U. Kimmeridgian – L. Porlandian) (Fyledal Clay, Vitabäck Clays)

APPENDIX II

LIST OF DIAGNOSTIC OSTRACODES

Cristacythere betzi – Cristacythere crassireticulata Zone (L. Sinemurian)

Cristacythere betzi (KLINGLER & NEUWEILER) (M. – U. Döshult Member)
Cristacythere crassireticulata MICHELSEN (M. – U. Döshult Member)
Pseudomacrocypris subtriangularis MICHELSEN (M. – U. Döshult Member)
Acrocythere cf. gassumensis MICHELSEN (M. – U. Döshult Member)

Ogmoconchella danica Zone, _Progonoidea reticulata_ Subzone (U. Sinemurian)

Ogmoconchella danica MICHELSEN (U. Döshult, Pankarp, Katslösa Members)
Progonoidea reticulata (KLINGLER & NEUWEILER) (U. Döshult Member)

Ogmoconchella danica Zone, _Gramannella apostolescui-Kinkelinella (Klinglerella) foveolata_ Subzone (L. Pliensbachian)

Ogmoconchella danica MICHELSEN (U. Döshult Member, Pankarp, Katslösa Members)
Gramannella apostolescui (GRAMANN) (Katslösa Member)
Kinkelinella (Klinglerella) foveolata MICHELSEN (Döshult Member and Katslösa Member)
Pleurifera harpa (KLINGLER & NEUWEILER) (Pankarp-Katslösa Members)

MIDDLE JURASSIC

Ostracode fauna not investigated

UPPER JURASSIC

VITABÄCK CLAYS :
Cypridea valdensis praecursor OERTLI
Fabanella mediopunctata MARTIN
Fabanella ornata (STEGHAUS)
Klieana calyptroides (ANDERSON)
Macrodentina retirugata (JONES)
Macrodentina transiens (JONES)
Mantellina purpeckensis (FORBES)
Klieana alata MARTIN

FYLEDAL CLAY:
Cytheropteron decoratum SCHMIDT
Damonella pygmaea (ANDERSON)
Klienana alata MARTIN
Klienana calyptroides (ANDERSON)
Macrodentina rudis MALZ
Rhinocypris jurassica (MARTIN)
Rhinocypris rasilis CHRISTENSEN

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Periodical title words in the present references are abbreviated in accordance with the American National Standards Institute, Standards Committee Z39, 1970: International List of Periodical Title Word Abbreviations.

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GLOSSARY

Allochtonous coal-seam:	Coal formed by transported plant litter, i.e. detritus from plants growing elsewhere.
Alluvial cone:	Steep cone-shaped mass of rock debris deposited by stream where its gradient abruptly diminishes. Alluvial cones commonly occur on the footwall side of vertical faults.
Arenite:	Consolidated sedimentary rock composed of sand-sized fragments irrespective of composition; e.g. sandstone, arkose, calcarenite.
Anoxic conditions:	Oxygen deficient conditions.
Arkose:	A feldspar-rich sandstone, typically coarse-grained and pink to reddish. Generally derived from rapid disintegration of granitic rocks.
Authigenic mineral:	Mineral grain precipitated on or within a sediment or sedimentary rock, i.e. not transported.
Autochtonous coal-seam:	Coal bed that originated at the place where its constituent plants grew and decayed.
Berthierine:	Greenish trioctahedral Fe-rich clay mineral with the general formula $(Fe,Mg,Al)_3$ $(Si,Al)_2$ $O5(OH)_4$. The mineral is commonly found in marine oolitic ironstones.
Biota:	All living organisms of an area.
Bioturbation:	The reworking and stirring of a sediment by organisms.
Bitumen:	Inflammable hydrocabron particle substantially free from oxygenated bodies and solvable in carbon disulfide. Natural asphalt is an example of bitumen.
Botryococcus:	Microalgae living in a lacustrine shallow environment.
Caliche nodules:	Nodules of calcium carbonate precipitated in soils of semi-arid regions due to evaporation.
Chamosite:	A greenish-grey or black mineral belonging to the chlorite group, $(Mg,Fe)Fe_3^{3+}(AlSi_3)O_{10}(OH)_8$.
Charred rootlets:	Blackish, porous, burnt roots, cf. charcoal.
Cone-in-cone structure:	An early diagenetic sedimentary structure involving cone-shaped deformation of carbonate-rich mudstones.
Crevasse splay:	A fan-shaped body of sediments deposited as a result of break through a river levee. The splay has a limited lateral and vertical range and is characterized by a fining upward sequence.
Crucible:	Melting pot of earthenware.
Debris flow:	A downwards moving mass of rock frag ments, soil, and mud. More than half of the particles being larger than sand size.
Dessication mark:	A crack in a sediment layer produced by drying and subsequent shrinking of the layer.
Detritus:	Fragmental material such as sand, silt and clay derived from abrasion and disintegration of older rocks and moved from its place of origin.
Diagenesis:	Chemical, physical and biologic changes of a sediment after its initial deposition, and during and after its lithification.
Diplocraterion:	U-Shaped vertically oriented trace fossil found in near-shore marine sandy deposits.
Echinate:	Spiny surfaced. Having a sculpture consisting at spines.
Eodiagenesis:	Early diagenesis, i.e. the regime at or near the surface of sedimentation where

the chemistry of interstitial waters still is mainly controlled by conditions of the surface environment.

Eustatic sea-level changes: Worldwide sea-level changes. These are controlled by variations in the amount of water tied to polar ice caps, loss of sea water in subduction zones, and the spreading of new seafloor along the mid-ocean ridges.

Facies: Characteristics of a rock unit, usually reflecting the conditions of its origin.

Flaser bedding: Heterolitic bedding containing ripple cross-lamination in which mud streaks are preserved in the troughs but incompletely or not at all on the crests.

Fluid inclusion: Aqueous inclusion entrapped in tiny mineral cavities by surrounding mineral growth.

Glaucony: General term for greenish grains of either glauconite, berthierine or chlorite.

Glauconite: A dull-green earthy or granular-mineral of the mica group $(K,Na)(Al,Fe^{+3}, Mg)(Al,Si)_4O_{10}(OH)_2$. Preferably formed in marine sediments.

Gorge: A narrow deep valley with nearly vertical rocky walls.

Heterolitic bedding: A closely interbedded deposit of sand and mud. Three types occur, viz. lenticular bedding, wavy bedding and flaser bedding, in order of decreasing content of mud laminae. These bedding types all comprise sandy ripple-marks covered by mud laminae of variable thickness and continuity.

Hercynian: Late Palaeozoic orogenic era in Europe, extending through the Carboniferous and Permian. Synonymous with the Variscan orogeny.

Hinterland: An area bordering an orogenic belt on the internal side. Also a term for a sediment-giving area in provenance studies.

Ichnotaxon: Trace fossil groups specified as species, family or class.

Illite: Mica-like clay mineral widely distributed in argillaceous sediments.

Intertidal flat (=tidal flat): Nearly horizontal marshy or barren tract of land that is alternatingly covered and uncovered by the tide.

Ilmenite: Opaque placer mineral ($FeTiO_3$). Ilmenite is a common constituent in sandstones derived from basic igneous rocks.

Inversion tectonics: The formation of deep basins in areas formerly occupied by uplifted land or vice versa.

Kaolin: Clay composed largely of the clay mineral kaolinite.

Kaolinite: Clay mineral with the general formula: $Al_2Si_2O_5(OH)_4$.

Kimmerian: Tectonic phase from the Late Triassic to the Jurassic–Cretaceus transition.

Lacustrine: Produced or formed in lakes.

Macrophyta: Large plants in an aquatic environment..

Methanogenic zone: Diagenetic zone of a sedimentary column wherein bacteria produce methane. This can occur at burial depths down to 1000 m..

Meteoritic flushing: Percolation of atmospheric water in a deposited sediment.

Montmorillonite: A group of expanding clay minerals.

Mud draping: Thin laminae of mud covering a positive bedform.

Oolite: A sedimentary rock composed of small, concentrical, sphaerical grains (ooids).

Playa lake: A shallow, intermittent lake in an arid or semiarid region.

Palaeosol: A buried soil profile of the geologic past.

Paraconglomerate:	Matrix-supported conglomerate, normally containing more matrix than large clasts.
Poikilotopic fabric:	Large diagenetic crystals enclosing several smaller mineral grains.
Progradation:	The building forwards or outwards towards the sea of a shore-line by nearshore deposition.
Redbeds:	Clastic sedimentary rocks wherein the grains are coated by iron oxides (haematite).
Rootlet beds:	Beds characterized by the presence of fossil plant roots.
Ripple marks:	An undulatory surface consisting of alternating subparallel small-scale ridges and hollows at the interface between a flo wing or oscillating fluid and a sand.
Scabrate:	Sculptured surface of pollen.
Scabrate-Echinate:	Sculptured spiny surfaced pollen.
Siderite:	Mineral of the calcite group ($FeCO_3$).

Distribution

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