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## Contents



## Abstract

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The Lund Sandstone constitutes a major coarse clastic deposit at the northeastern border of the Danish Subbasin. The sandstone is mapped and described from 20 borings and 420 km of reflection seismics in a 10 to 15 km wide zone from Landskrona to Skurup. The petrography includes a complex sequence of alternatingly quartzose sandstones, calcareous sandstones, arenaceous limestones and argillaceous limestones. The microfossil fauna suggests a Santonian to Campanian age. The deposition was coincident with subsidence of the area southwest of the Romeleåsen Horst, which indirectly led to the accumulation of up to 845 m of clastic sediments in the depocentra along the horst. Three major depositional centra are found, the Kyrkheddinge, Lund and Landskrona areas. The association of lithofacies together with the structural development indicates a nearshore and inner shelf depositional environment during the studied interval. Subenvironments include longshore sandbars, channel distributary mouth bars, offshore delta fronts and interdistributary bays. The palaeogeographic reconstruction gives a northwestward extending shoreline in front of an uplifted area to the northeast which was transected by a system of rivers transporting eroded clastics into the basin where a number of local deltas were formed. These environments persisted during most of the Campanian due to subsidence and uplift movements which coincided with the sedimentation in the area.

## Introduction and geological setting

Upper Cretaceous strata are distinguished in five separate areas in Scania. Four of these, i.e. the Vomb, Kristianstad, Båstad and Hanö Bay Basins, are situated within or immediately northeast of the Fennoscandian Border Zone (Fig. 1). This zone forms a tectonically disturbed area of block-faulted Precambrian rocks, early Palaeozoic sediments and late Triassic to late Cretaceous sediments (Pegrum 1983) acting as a fringe zone between the Danish Subbasin in the SW and the more stable Fennoscandian Shield in the NE. The zone stretches from the Skagerrak through the Kattegatt and Scania towards Bornholm (Baartman & Christensen 1975). The fifth area, the SW part of Scania constitutes a marginal part of the Danish Subbasin included in the Danish Polish Trough.

The Santonian-Campanian sediments encountered in these areas consist of dominantly sandy siliciclastic material alternating with argillaceous limestones and claystones (Brotzen 1942, 1945; Bergström et al. 1973; Bergström in Kornfält et al. 1978; Kumpas 1979, 1980; Chatziemmanouil 1982).

The deposition of these sediments was strongly influenced by the structural pattern of Scania that developed during late Mesozoic time. Three major structural units can be distinguished in Scania: From the southwest the Danish Subbasin, the NW-SE trending Fennoscandian Border Zone and the Fennoscandian Shield (Fig. 1). Southwestern Scania constitutes only an eastern part of the Danish Subbasin which is approximately 200 km wide across and extends lengthwise from Poland and the southern Baltic into Scania and through Zealand and Jutland into the North Sea.

The Danish Subbasin was probably initiated during late Palaeozoic time, as indicated by the findings of Permian volcanic rocks in deep borings in the Danish part of the basin (Baartman & Christensen 1975; Liboriussen et al. 1986). This coincides also with the tectonic instability of Europe during the Variscan Orogeny. Permian sediments were as yet found in Scania but radiometric and paleomagnetic datings of dolerites (Mulder 1971; Bylund 1973; Klingspor 1976) implicate that there occurred an extensive fracturing of Scania during this period. Magmas penetrated through NW striking fractures and are today found as dolerites transecting the Scanian Palaeozoic cover rocks (Bergström et al. 1982).

During the Mesozoic the Danish Subbasin continued to subside and thick piles of siliciclastic sediments were deposited. At the end of the Triassic a new tectonic phase commenced, the Kimmerian disturbance, which again caused extensive faulting due to tension and downwarping of the Scanian bedrock (Bölau 1973; Baartman & Christensen 1975; Norling 1984, 1985; Bergström 1985; Norling & Bergström 1987; Liboriussen et al. 1986). Volcanism occurred in the central parts of Scania. The unstable phase ranged from the Upper Triassic into the Early Cretaceous and caused a wide spectrum of different sedimentary environments which are represented in the sedimentary record. Widespread block-faulting led to large variations in sediment thickness since movement of separate blocks was rejuvenated repeatedly during the Mesozoic. During the Late Cretaceous continued subsidence in the Danish Subbasin caused by the Sub-Hercynian orogenic phase, lead to the formation of thick Upper Cretaceous deposits (Norling & Skoglund 1977; Bergström 1985; Liboriussen et al. 1986). The total net subsidence of the Late Cretaceous generally exceeded 1000 m (Bergström et al. 1982) and was greatest in Santonian, Campanian and Maastrichtian times (Norling & Skoglund 1977; Bergström 1985).

The Danish Subbasin in Scania with its Cretaceous deposits is bordered to the northeast by the NW trending Romeleåsen Fault and Flexure Zone which transects Scania from Ystad to Helsingborg (Fig. 1). The major movements along this line appear to have occurred in the Early Campanian (Baartman & Christensen 1975).

The Upper Cretaceous of southwestern Scania includes two major sandstone sequences in the otherwise dominantly calcareous sedimentary column. A Cenomanian sandstone is found at comparatively great depths (Brotzen 1945) and is

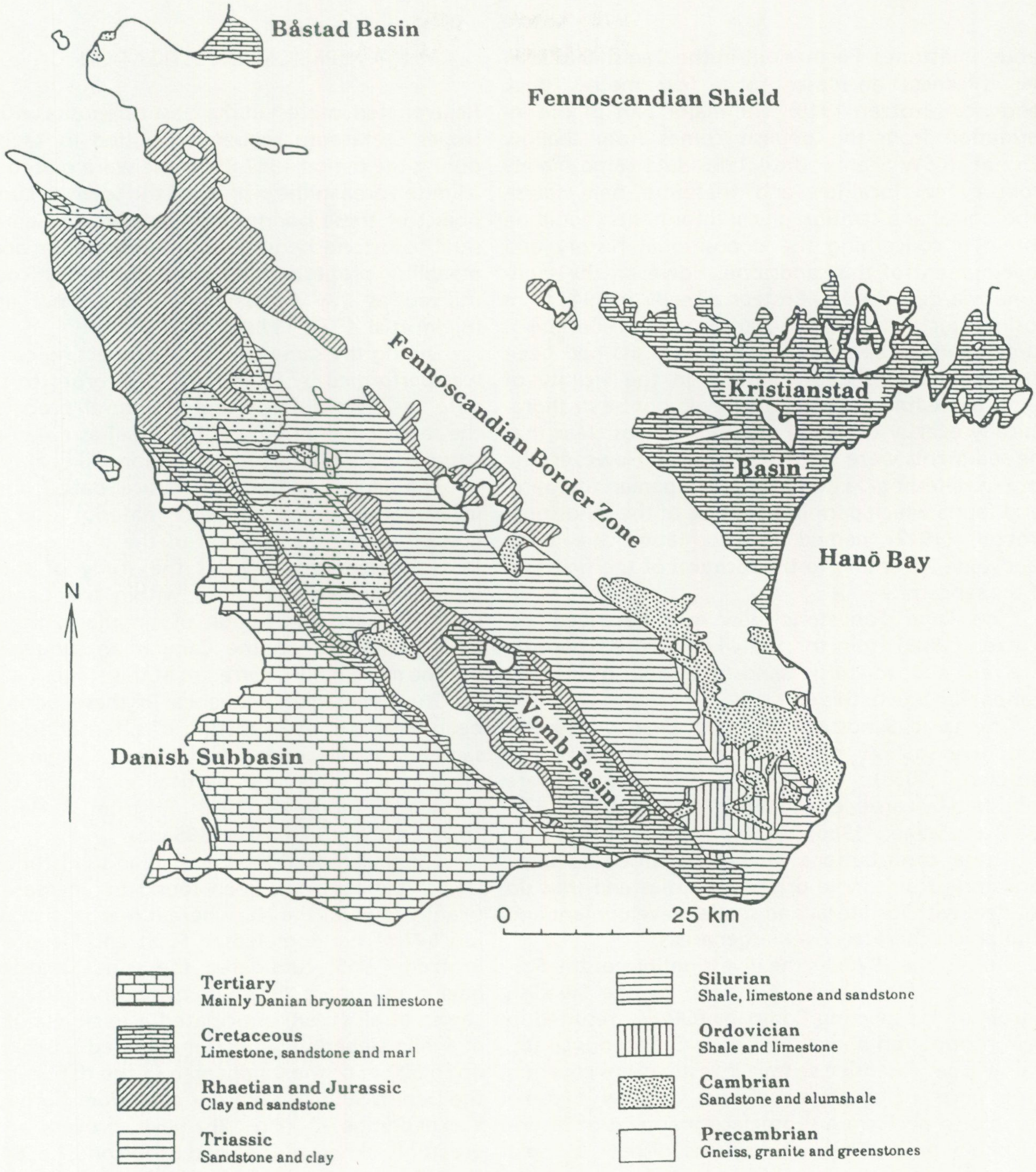


Fig.1. Simplified bedrock map of Scania.

relatively well known from seismic data and borings. The other sandstone sequence is of Santonian - Campanian age. This unit has a continuous distribution and development in a zone close to and parallel to the Romeleåsen Fault and Flexure Zone. According to data presented in this paper it comprises up to 845 m thick deposits mainly consisting of poorly consolidated sandstones interbedded with argillaceous limestones. Further out in the Danish Subbasin the thickness decreases to a few metres thick sequence (Brotzen 1945). The major part of the information from this deposit comes from shallow borings in SW Scania. Until 1986 data came mainly from a few localities and therefore only sparse lithological and stratigraphical information could be obtained concerning the depositional history and development of this sandstone. However, the sandstone was described by Brotzen already in 1942 from borings just east of Landskrona, e.g. Hilleshög-1. Some years earlier similar sandy deposits had been encountered in shallow borings in the vicinity of Lund. These findings could however, not be stratigraphically exactly classified although it was clear that the sediments were Upper Cretaceous. However, the core in Hilleshög-1 contained a Campanian foraminiferal fauna which permitted dating of the sandstone. Brotzen (1942) named the formation the Lund Sandstone according to the location of the first find of the sandstone.

The Lund Sandstone was also described by Brotzen (1945) from the Höllviken-1 core where he referred a 1 m thick sandstone bed of Middle Campanian age to this unit.

The Lund Sandstone has also been described from five shallow borings in the vicinity of Lund (Brotzen, 1953). Additional descriptions were published by Larsen et al. (1968), Norling (1976, 1978, 1980) and Sivhed (1986).

These contributions mainly describe the Lund Sandstone from single or few localities and thus do not deal with its lateral and spatial development and lithological character over larger areas.

During the 1970-ies the investigations of the Scanian part of the Danish Subbasin by the Swedish Petroleum Prospecting Company (OPAB) resulted in new information about the Upper Cretaceous strata, mainly from extensive seismic investigations covering large parts of southwest Scania. It now became possible to perform a subsurface mapping of distinguishable units. The seismograms display a rapid increase in thickness of the Upper Cretaceous strata from the southwest towards the Romeleåsen Fault and Flexure Zone. It can also be seen that there are several local thickenings of the Upper Cretaceous sediments close to the horst. Since none of OPAB:s subsequent borings were located in the area of greatest thickness uncertainty still remained about the actual lithology of the Upper Cretaceous deposits close to the horst. Since no hydrocarbons were found the OPAB activity in the ended in 1973.

## PRESENT INVESTIGATION

Rejuvenated interest in the clastic deposits within the Upper Cretaceous sequence resulted in 17 borings during the period 1982-85. These were placed within a limited area in the vicinity of the town of Lund. The object of these borings was mainly the Campanian sand/sandstone beds. Their high porosity and permeability properties indicated that they could be utilized as low temperature geothermal aquifers (Bjelm et al. 1977, 1979).

During the same period a prospecting campaign was performed by Swedegas AB in order to investigate the petrophysical and structural properties of the sandstone aquifer and potential as a natural gas storage in SW Scania (Chatziemmanouil et al. 1981).

The geological and geophysical data from these investigations form the major material used for the present work. The location of the borings within a fairly limited area favours the study of the local sedimentological variations within the Campanian succession and correlation of singular units. Other borings penetrating the Campanian sequence will only be marginally referred to at this stage.

The Campanian sequence in these borings has been described as consisting of alternating beds of sand and argillaceous limestone with varying petrography, thickness and vertical extension (Cherns, Larsson & Thoregren 1983; Erlström & Hesselbom 1984; Erlström & Eriksson 1985a, b).

The thickness of the Campanian sandstone in the Danish Subbasin has been found to increase significantly towards the NE, where it reaches a maximum just SW of the Romeleåsen Fault and Flexure Zone. Brotzen (1945) considered the Lund Sandstone to have a maximum thickness of approximately 60 m. Larsen et al. (1968) anticipated a thickness of >100 m, while Lieberkind (1984) mentioned a thickness of up to 500 m of the Campanian in the depocentras of the Danish Subbasin. Recent data from borings, e.g. Kyrkheddinge1-7 (Fig. 2), have proven an even greater thickness of the Lund Sandstone, i.e. 845 m in Ky-7 (Erlström & Hesselbom 1984).

The variation in thickness and character in the Campanian sediments, indicate a fluctuating depositional environment. According to interpretations the depositional environments included high energy shallow environments, such as beaches and progressive deltas, alternating with more quiet environments in somewhat deeper water (Chatziemmanouil et al. 1981).

The large number of observations of the Lund

| | DANIAN | MAASTRICHTIAN | | | CAMPANIAN/SANTONIAN |
|---|---|---|---|---|---|
| Lithological units and formations / BORINGS | Bryozoan limestone (unnamed formation) | chalk formation | Hansa formation | Argillaceous limestones (unnamed formation) | Lund Sandstone |
| Svedala-1 | 55 | 258 | — | 398 | 24 |
| Mossheddinge-1 | —— 276 —— | | 4 | 336 | 310 |
| Kyrkheddinge-1 | —— 168 —— | | — | 217 | >427 |
| Kyrkheddinge-2 | —— 86 —— | | — | 222 | >546 |
| Kyrkheddinge-3 | —— 170 —— | | — | 259 | >403 |
| Kyrkheddinge-4 | 23 | 123 | — | 224 | >458 |
| Kyrkheddinge-5 | —— 171 —— | | — | 236 | >319 |
| Kyrkheddinge-6 | —— 114 —— | | — | 227 | >664 |
| Kyrkheddinge-7 | —— 94 —— | | — | 225 | 845 |
| Flackarp-1 | — | 150 | 15 | 260 | >283 |
| Värpinge-1 | — | 121 | 36 | 187 | >343 |
| Värpinge-2 | 42 | 114 | 36 | 242 | >192 |
| Värpinge-3 | 37 | 113 | 37 | 245 | >175 |
| Värpinge-4 | 58 | 115 | *38* | 190 | >249 |
| Skälsåker-1 | 43 | 136 | *34* | 265 | >191 |
| Skälsåker-2 | 66 | 135 | *30* | 274 | >132 |
| Hansagården-1 | 43 | 137 | *55* | 237 | >170 |
| Barsebäck-1 | —————— 495 —————— | | | | >412 |
| Norrevång-1 | —————— 632 —————— | | | | 580 |
| Nyhem-1 | — | 170 | — | 280 | >450 |

Fig. 2. Thickness in metres of the different lithological units and formations in the borings included in this study. Where the Lund Sandstone has not been completely penetrated the thickness is preceeded by a larger-than-sign.

Sandstone have so far not been compiled into a comprehensive presentation. This investigation will compile the available and heterogeneous data and improve the interpretation of the depositional environment of the Lund Sandstone. However, the extent of the presented investigation is largely governed by the availability of data from the different borings and by the condition of the core and cutting material. The suggested depositional model is consequently based mainly on descriptions of lithofacies and successions of lithofacies from cuttings. Sedimentary structures are largely missing in the descriptions. This has to be considered in any appreciation of the presented model.

## Adjacent Santonian-Campanian depositional areas

Despite regressional-transgressional events resulting from the opening of the North Atlantic and attendant tectonics, and subsequent denudation phases, Campanian and Santonian strata are well represented in all Scanian areas (Fig. 3). The Upper Cretaceous sedimentary sequence is generally thin and occasionally incomplete in other areas in comparison with the condition in the Scanian part of the Danish Subbasin. This is particularly true for the shallow Kristianstad and Båstad Basins.

The faunal composition indicates that most of the Santonian and Campanian strata were deposited in a turbulent, upper shelf environment less than 200 m deep (Gabrielson & Holland 1984).

### THE KRISTIANSTAD BASIN

The basin consists of a gently SW-dipping depression of the crystalline basement bordered by faults to the SW. It constitutes the onshore continuation of the Hanö Bay Basin. Two faults, the Linderödsåsen and Nävlingeåsen Faults, bound the basin to the SW. To the N and NE the thickness of the Cretaceous cover decreases significantly and shows an erosional irregular boundary (Lidmar-Bergström 1982) which formed during Tertiary and Quaternary times. The maximum thickness of the sediments in the Basin is approximately 200 m, of which Santonian and Campanian strata comprise the major part (Bergström in Kornfält et al. 1978; Christensen 1975, 1984). The sediments are mainly of marine origin and consist mainly of bioclastic rudites, arenites and lutites, and of more or less calcareous sandstones. Glauconitic sandstones, conglomerates and clays are only locally found in the sedimentary sequence (Bergström in Kornfält et al. 1978).

To a large extent the depositional environment was governed by local variations in the influx of terrigenous clastics coming from the surrounding horsts in the south and the irregular Cretaceous shore-line in the north. Nearshore sandbars and conglomerates have been identified at Ullstorp (Erlström & Gabrielson 1986; Erlström 1986) and a rocky coastline at Ivö Klack (Surlyk & Christensen 1974).

### THE HANÖ BAY BASIN

Upper Cretaceous deposits have been verified in two borings and in seismic profiles (Kumpas 1979, 1980). The Hanö Bay acted as a sedimentary basin during the Mesozoic. The Linderödsåsen Fault extends into the Hanö Bay and joins the Christiansö Fault north of Bornholm (Kumpas 1980; Bergström, Kumpas, Pegrum & Vejbaek 1987)). This joined structure constitutes the southern limit of the Santonian and Campanian sediments. To the north the basin has an extensional limit just outside the coast of Blekinge. To the SE the basin extends into Polish syn-depositional areas.

The Upper Cretaceous sediments were deposited in a rapidly subsiding basin mainly during transgressive periods as in the Kristianstad Basin. The Santonian has an estimated average thickness of 400 m in the southern part of the basin, with gradually thinning strata towards the north. The sediments consist mainly of biocalcarenites, shelly limestones and sandstones (Kumpas 1980).

The Campanian has a greatest known thickness of 43 m. This stage is missing in the northernmost parts of the basin. The sediments consist mainly of sandstones and bioclastic limestones with occasional conglomerate beds.

### THE VOMB BASIN

The Vomb Basin consists of a narrow elongate asymmetrical graben, 7-11 km wide and 80 km long, initiated during the Late Cretaceous (Norling & Bergström 1987). To the NE it is bordered by the Fyledalen Fault, SW of the Silurian Colonus-shale

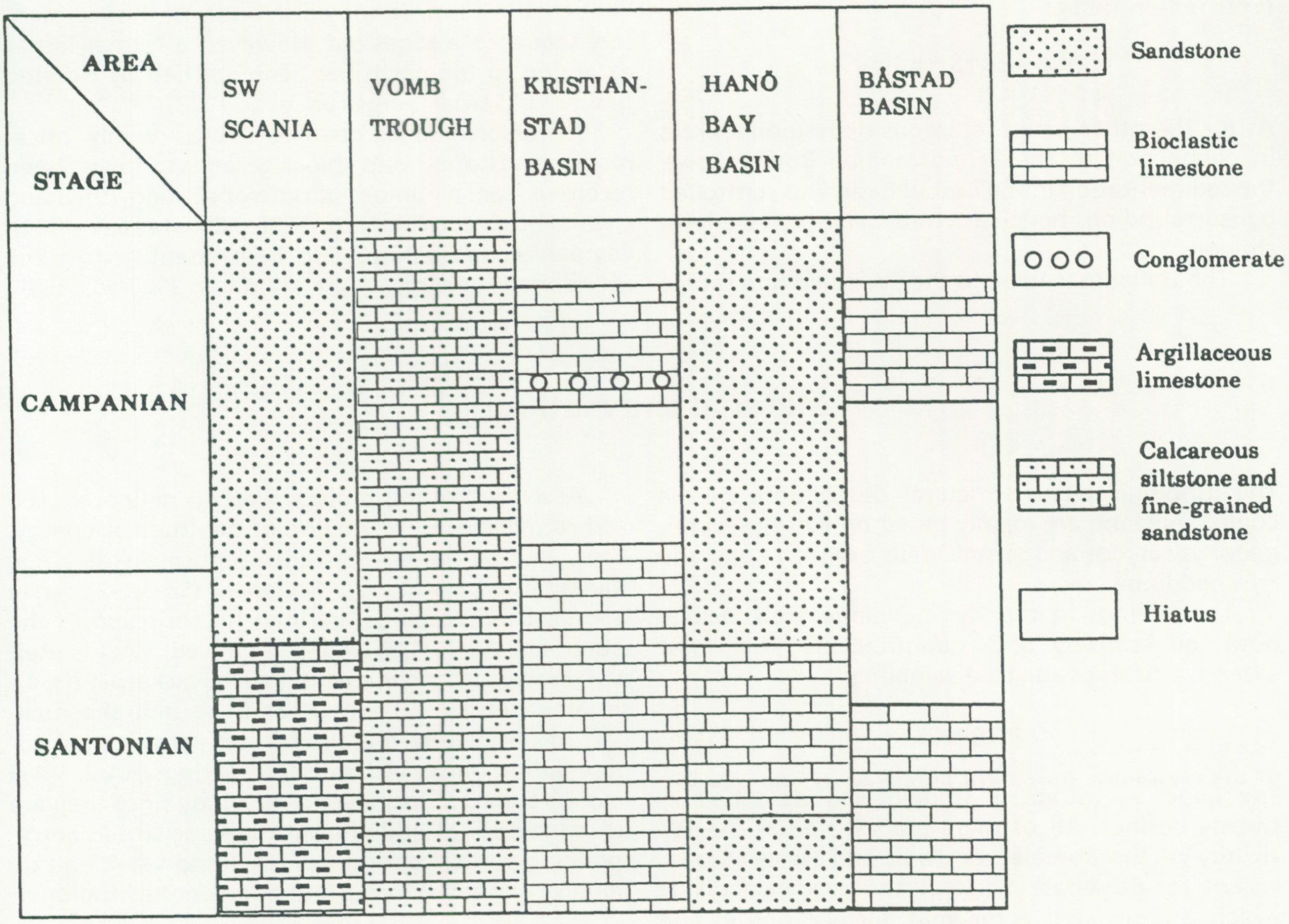


Fig. 3. Schematic illustration of the occurrence of Santonian and Campanian strata in Scania (modified after Christensen 1984)

Trough (cf. Fig 1 & 2 in Norling & Bergström 1987). To the SW the extension of the Vomb Basin is bordered by the Romeleåsen Horst. The Upper Cretaceous is mainly known from a limited number of outcrops (Christensen 1986) and five borings (Norling 1981; Chatziemmanouil 1982). As in the Hanö Bay Basin the Santonian consists of a comparatively thick sedimentary sequence. A maximum thickness of 387 m is found in the Kullemölla area. Glauconitic argillaceous siltstones interbedded with sandstones and claystones constitute the main lithologies (Chatziemmanouil 1982). Beside a general decrease of the argillaceous content in the Campanian sediment there does not seem to be any major lithological difference between the two stages. The Campanian is approximately 160 m thick. The sediments were probably deposited in a shallow marine environment with moderate water energies, at least, in comparison with the previously described areas (Chatziemmanouil 1982). However, outcrops in the Vomb Basin display a wider spectrum of depositional environments including imbricated conglomerates of nearshore origin. The sedimentation in the Vomb Basin was probably coincident with a global transgression during Late Cretaceous times with a maximum during the Coniacian and Santonian (Christensen 1986).

### THE BÅSTAD BASIN

As for the other Late Cretaceous depositional areas in connection to the Fennoscandian Border Zone, the sedimentation in the Båstad Basin was controlled by surrounding horst-structures and by sea-level changes.

The Hallandsås horst in the SW acted as a source for terrigeneous clastic material entering the basin and at the same time constituting a distinct extension limit for the basin. To the north and east the sedimentary sequence wedges out. However, a former larger extension to the north has been verified by isolated findings at Särdal (Bergström et al. 1973).

Santonian and Campanian strata, mainly calcareous sandstones and biocalcarenites, have been recorded from a number of outcrops (Hägg 1954) and erratic boulders (Moberg 1886; Christensen 1984). Campanian strata have also been identified in the abandoned limestone quarry at Malen (Sivhed 1983).

## Material and methods

The lithological and structural descriptions of the Lund Sandstone are mainly based on cuttings, cores, geophysical logs and seismic data from the Lund and Kyrkheddinge area.

The borings in the Kyrkheddinge area include both qualitatively and quantitatively the most extensive cuttings and core-sampling.

### BORINGS

The Lund Sandstone is studied and described in twenty borings. All of them are situated in the SW vicinity of the Romeleåsen Fault and Flexure Zone, except for Barsebäck-1 (BA-1) and Svedala-1 (SV-1) which are situated somewhat further out in the Danish Subbasin (Fig. 5). BA-1, Norrevång-1 (NV-1) and Mossheddinge-1 (MO-1) were drilled by OPAB in the search of hydrocarbons in SW Scania. SV-1 was drilled by the Geological Survey of Sweden in 1949 for subsurface mapping purposes.

Nyhem-1 (NY-1) was drilled by the Lund Institute of Technology for geothermal purposes (Bjelm & Persson 1981). The borehole is located in the area immediately SW of the fault and flexure zone E of Landskrona. In the Lund-Kyrkheddinge areas a total of 18 borings have been drilled into or through the Lund Sandstone at depths from approximately 350 m and downwards.

The seven Kyrkheddinge borings (KY-1-7) were drilled by SWEDEGAS AB with the main object to investigate the potential of storing natural gas in the Lund Sandstone aquifer. They were drilled during the years of 1982-84. Within the framework of the geothermal project referred to earlier in the Lund area a total of eleven borings were drilled into the Lund Sandstone aquifer.

As a result of this project, water is now produced and recircled after extraction of geothermal energy. Thus, four of the borings are producing water, i.e. Hansagården (HA-1, -2), Skälsåker (SK-1, -2) while borings from Värpinge are used for recircling of the water, i.e. VÄ-3, -4, -5 and -6. One well, VÄ-1 is used as a reserve and the remaining well, Flackarp-1 (FL-1), situated between the Kyrkheddinge and the main part of the geothermal production area, is used for observation purposes. The three borings HA-2, VÄ-5 and VÄ-6 are not included in this study since they are deviated borings drilled from the same site as corresponding vertical boring, i.e. HA-1 and VÄ-4, and do not give any additional information on the lithology.

#### Cuttings

The predominant part of the available lithological descriptions is based on cuttings collected at three metres intervals on an average and also occasionally at two or five metres intervals. The sample-intervals for each section and borehole are compiled in the Appendix together with pertinent data. The quality of the cuttings varies greatly depending on type of drill-bit, induration of the rock, sampling equipment on the rig, e.g. screen size of the shale-shakers, presence of desilter and desander and post sampling treatments at the well-site.

KY-1, -2, -3, -5, -6, -7 and NY-1 have been drilled with a slim-hole technique which yields occasionally very small-sized cuttings, compared with conventional drilling methods. If a button-bit instead of a roller-bit was used in hard rock lithologies, grinding of the rock results in small cuttings on which a proper description of the lithology can be difficult to perform. The cuttings were described quantitatively and qualitatively at the well-site and presented in a lithological log. When properly compiled these logs are referred to in this study. Others have been redescribed to get a standard lithological description.

### Cores

The most continuous coring through the Lund Sandstone was performed in KY-1, -2, -3 and -4. Only minor coring took place in other borings i.e. 1.5 m in FL-1 and 1.5 m in SK-1. Continuous coring was also performed in SV-1, but there the Lund Sandstone is of less significant thickness and not as well developed as in the wells situated closer to the Romeleåsen Horst.

Cores are generally missing in loose or poorly consolidated intervals. In such sections lithological descriptions have largely been based on geophysical logs, rate of penetration during drilling and on cuttings. Cores cut in the KY-4 and FL-1 consist of large diameter core (95 mm in diameter) while the main part of the other available core material consists of small diameter cores (42 mm).

After a general lithological description the cores have been sampled for thin section, X-ray diffraction and chemical analyses. The cored sections are compiled for each well in the Appendix.

### Geophysical well logs

A wide spectrum of different geophysical data is available from the different borings. These data consist mostly of measurements of formation resistivity, conductivity, natural radiation, response to radiation and sound wave velocity. The results from the logging are normally presented on logsheets of various types. The results vary greatly between borings and with hole conditions, choice of instrument and the company that performed the measurements. It is therefore occasionally difficult to correctly correlate different geophysical responses of a certain lithology between borings. However, the logs are used as valuable instruments to distinguish beds with significant geophysical characters, such as clays, sand/sandstone and limestone. The gammaray, selfpotential, resistivity and density logs are usually preferred in this study since they yield the most reliable information on petrophysical characters of importance for the interpretation of lithological properties. Geophysical data from the Kyrkheddinge borings comprise the most uniform and complete material and therefore constitute the basic material in this study. The type of geophysical logs that were run and the intervals covered is presented for each borehole in the Appendix.

## SEISMICS

Most of the data in this study derive from seismic lines shot in the years 1969-1981 by OPAB during their hydrocarbon exploration program in Scania.

The reflection seismics shot SW of the Romeleåsen Horst comprise a total of 761 km along 55 profiles. All of these are not included in this study which involves interpretation of approximately 350 km seismics shot by OPAB, mainly in a 25 km wide zone along the Romeleåsen Fault and Flexure Zone, from Skurup to Landskrona. Most of the lines run perpendicular to and across the direction of the main NW-SE lineament with an average spacing of 10 km. Three of the interpreted lines run parallel to the Fault and Flexure Zone.

The quality of the data varies considerably. Older records are generally poorer since both data acquisition and processing technique have advanced considerably during the exploration period. The quality of the Upper Cretaceous markers also depends on the target levels for the seismics. These were mainly focussed to deeper formations, which resulted in poor resolution for markers in the Lund Sandstone. Beside the OPAB seismics there have been additional reflection seismic investigations performed in the Kyrkheddinge, Mossheddinge, Svedala and Skurup areas during 1981-83 by SWEDEGAS AB. Their seismics were mainly focussed on Upper Cretaceous clastic units, which resulted in significantly improved quality and resolution of the seismic markers as compared with older OPAB data.

The seismic results have been used as an important data base for the compilation of contour isochron maps for top and base of the treated formation, thus characterizing the subsurface conditions. These contour maps are expressed in two way travel time (TWT, measured in milliseconds). It has not yet been possible to perform any satisfactory metric depth conversion of these data since there are very few velocity control measurements available.

Two major markers representing the base and top of the Lund Sandstone have been mapped in the investigated area. The upper one of those is the Tan marker, which represents the top of the formation, while the lower, the Yellow marker is taken to represent the base. The markers were picked and characterized in the Kyrkheddinge area, from where they were traced and followed laterally into the adjacent areas. Due to the shifting quality of the records, there are difficulties to follow the markers in the Landskrona, Skurup and Svedala areas. Hence the map quality is inferior in these parts of the maps.

## LITHOLOGICAL DESCRIPTIONS

The main part of the lithological descriptions of cuttings and cores carried out at the well-site from the Kyrkheddinge and Lund areas was only slightly modified in this study. The descriptions concerning the Lund Sandstone from the other borings are renewed to various extent. This was performed in order to obtain a uniform characterization of the material.

The lithological descriptions of the cuttings were performed according to standard procedures. First a quantitative estimation of the observable components making up the framework and matrix was carried out. With minor exceptions these components included sand, silt, clay, calcareous material, coal, pyrite and glauconite. In this way an average composition of the lithology was compiled. Second, a qualitatively more detailed description was performed of fabric, sorting, matrix, miscellaneous minerals and when possible also the macro- and microfossil composition. Each represented lithology is described separately even if the cutting material includes several lithologies in the same sample.The question, whether such mixtures represent contamination or if they are evidence of alternating or interbedded lithologies was tentatively answered with the aid of geophysical logs and rate of penetration during drilling.

## MODAL ANALYSES

A point count analysis was conducted on 202 thin sections from cored sections in the Kyrkheddinge borings to determine the modal composition of the different lithofacies. Thin sections of cuttings were included in this analysis only to a minor extent , i.e. from 12 samples in FL-1 and VÅ-1.

An average of 500 points were classified into ten different groups, i.e.detrital, void, matrix,cement, feldspar, skeletal fragments, coal, opaque minerals, mica, and glauconite. The groups were chosen in order to give optimal information about framework-matrix relations, sorting and sediment classification. The modal analyses mainly resulted in information about the composition of more or less indurated lithologies, i.e. lithologies cemented or held together by either silica, calcite or clay. Modal analyses on friable or loose intervals were largely excluded since it was not possible to make thin sections of these sediments.

## X-RAY DIFFRACTION ANALYSES

The clay mineral composition in the matrix of the argillaceous limestones and in the arenaceous limestones of the Lund Sandstone formation was analysed from five different levels in KY-1, i.e. 675.4, 701.2, 726.6, 737.6, 795.0 m. Core material from the sampled levels was gently crushed in a mortar. The produced fines were dispersed in distilled water with added 0.05 M sodiumpyrophosphate ($Na_2P_20_7$), stirred to get a uniform suspension and the $< 2$ µm fraction separated by use of a Hettich Rotanta AP centrifuge. Oriented preparates were produced out of each sample by letting the suspension filtrate on a millipore membrane-filter, with pore-diametres of 0.47 µm, placed on a porous ceramic tile and attached to vacuum. The produced filter-cake was then transferred to a glass-slide and airdried. This technique was described by Drever (1973).

The XRD analysis was primarily carried out on un treated oriented preparates by use of a Phillips PW 1710 goniometer at a rate of 1° 2θ/min in the interval 2-40° 2θ. Identification of non-swelling and swelling clay minerals was done by ethylene glycol treatment at 60°C for 48 Hours. After this treatment the XRD analysis was repeated and evaluated again.

## CHEMICAL ANALYSES

The bulk chemical composition was determined by the use of X-ray fluorescence spectrometry. 40 samples were analysed from core material representing different depths and lithologies from the Kyrkheddinge borings. Several of the sampled horizons are also analysed for the modal composition.

The multicomponent analysis includes determination of a standard program of main components and trace elements performed on a Rigaku Simultrix spectrometer, after drying, grinding, mixing with cellulose, resin embedding, and production of a compacted briquette sample.

The amount of carbonate was analysed by gravimetry where the amount of evolved $CO_2$-gas was measured when a sample was treated with HCl.

### GRAIN-SIZE ANALYSES

Cuttings were processed for constituent and grain-size analyses from unconsolidated and poorly consolidated sandstone intervals. Analyses were mainly performed on samples from the Kyrkheddinge and Lund borings. Thus, on average every 6 metres in the upper 100 m of the Lund Sandstone and every 3 m from this level and down to TD were analysed in KY-1, -2, -3, -4. Due to insufficient material or significant contamination of the samples some borings and certain levels could not be analyzed.

Another 85 samples were analysed from KY-5, -6, -7, HA-1, SK-1, -2, VÄ-1, -2, -3 and -4 beside the analyses carried out in the above mentioned borings. A presentation of the sampled levels for each well is given in figures 22-24. Although coverage of the Lund Sandstone was the aim, the sampling depends on availability.

The sand grade material was sieved through a standard set of sieves by wet and dry sieving methods. The material was generally split into the following five fractions, very fine 0.075-0.125 mm, fine 0.125-0.25 mm, medium 0.25-0.5 mm, coarse 0.5-1.0 mm, and very coarse material > 1.0 mm. However, such a treatment is due to the sampling technique, i.e. cuttings, subdued to statistically significant sources of error which decreases the value of the analysis. However, the analysis give valuable information concerning trends in the overall grain-size distribution within the formation.

The statistical measures calculated include mainly mean grain-size and standard deviation (Folk & Ward 1957). After weighing each fraction a statistical treatment of mean grain-size and standard deviation was carried out on the material from KY-5, -6, -7, VÄ-4, SK-1, SK-2, VÄ-2, VÄ-3 and HA-1.

## Stratigraphy

### LITHOSTRATIGRAPHY

#### The Lund Sandstone

The Lund Sandstone in this contribution is ranked as a formation (Fig. 4). Although much is known about it, it still remains for instance to improve the knowledge on the character of the lower boundary. It has also to be remembered that ongoing investigations of the Upper Cretaceous in SW Scania may result in another ranking of the Lund Sandstone in the near future.

The most extensive data on the Lund Sandstone comes from the two borings KY-1 and KY-7. The geological information from these two borings include beside relatively complete cored sections (KY-1) also a well documented set of geophysical well-logs. However, the Lund Sandstone does not seem to be completely penetrated in the KY-1 boring. Its lithostratigraphy is therefore defined by a composite stratotype where KY-1 represents the upper stratotype (402-800 m) and KY-7 the lower stratotype (800-1070 m). The composite lithologs are illustrated in the appendix. The upper 200 metres of the Lund Sandstone are characterized by coarse and medium-grained calcareous sand and sandstone beds interbedded by arenaceous and argillaceous limestones. Siliciclastic beds dominate the section down to 600 metres depth where there is a transition into interbedded and frequently alternating lithologies of fine-grained sand and argillaceous limestone. Below 800 metres the formation is characterized by a high argillaceous content in its interbedded limestones. The proportion of units characterized as sand and sandstone decreases somewhat in comparison with the upper part of the formation. However, below 950 m there occur at least two thick units consisting of medium- and coarse-grained quartzose sand.

The lower boundary is set at 1070 metres depth in KY-7 since there occurs a change in the lithology towards more glauconitic and marly sediments. The marls are slightly greenish due to the glauconite content. The change in lithology together with the uniform seismic signal down to the Cenomanian sandstone indicates that there are most likely no deeper sand intervals than those defined as belonging to the Lund Sandstone in KY-7.

#### Underlying lithostratigraphical units

The Lund Sandstone is completely penetrated in only six of the twenty borings, i.e. SV-1, MO-1, KY-6, KY-7, BA-1, and NV-1. It is therefore difficult to characterize the underlying strata in the investigated area. The lithostratigraphical boundary between

| STRATIGRAPHY | | | MAIN LITHOLOGY | THICKNESS |
|---|---|---|---|---|
| QUATERNARY | | | Glacifluvium and till | 30-70 m |
| TERTIARY | | | | |
| | Danian | Unnamed formation | Biomicritic, silty bryozoan limestones | 20-80 m |
| Upper CRETACEOUS | Maastrichtian Upper | Chalk formation | Whitish chalk and pale grey, fine, hard, biomicritic limestones, with dark chert horizons | 120-180 m |
| | | Hansa formation | Slightly calcareous, medium to coarse-grained arenitic sandstone, variably consolidated, mainly loose, interbeds of arenaceous limestone, glauconite. | 5-55 m |
| | Maastrichtian Lower | Unnamed formation | Grey, fine argillaceous limestones and claystones, somewhat silty, mostly fairly hard although with some more plastic claystone units. Increasing quartz silt/sand content in lowermost beds. | 150-240 m |
| | Campanian Upper | Lund Sandstone | Calcareous, fine to medium grained quartzose sandstone/sand, variably clayey. Mostly poorly consolidated. Silica and calcite cemented beds oocasionally fairly abundant. Siliciclasitic intervals separated by units of argillaceous or arenaceous limestone, glauconite, coal and pyrite in variable amounts. | 24-845 m |
| | Campanian Lower | | | |
| | Santonian | Unnamed formation | Greenish grey, argillaceous, glauconitic limestones. | ? |

Fig. 4 Stratigraphy, main lithology and thickness of the different strata in the investigated area.

underlying units and the Lund Sandstone was furthermore found to be gradual and therefore difficult to define exactly.

It can be observed, however, that the underlying Santonian strata beneath the transition zone are composed of relatively homogeneous argillaceous biomicritic limestones, which frequently contain high amounts of glauconite (Fig. 4). Occasional layers are found to contain significant amounts of fine-grained rounded quartz grains. The sediments are generally well consolidated and cemented with calcite (Erlström & Hesselbom 1984).

## Overlying lithostratigraphical units

The Lund Sandstone is overlain by more than 300 m of Maastrichtian and Danian deposits in the area SW of the Romeleåsen Fault and Flexure Zone. The sandstone beds are strongly affected by Late Cretaceous tectonic movements along the Fault and Flexure Zone with the result that strongly deformed Upper Cretaceous strata constitute the bedrock surface in a narrow zone close to this lineament (Fig. 5).

The maximum thickness of the overlying sediments is found in the distal borings included in this study, i.e. 495 m in BA-1, 632 m in NV-1, 711 m in SV-1 and 616 m in MO-1 (Fig. 2). These borings are situated further out in the Danish Subbasin compared with the borings in the Kyrkheddinge, Lund, and Nyhem areas, where the overlying sediments are considerably thinner, on average 350-400 m thick.

The Maastrichtian consists mainly of limestones and fine-grained clastic sediments (Fig. 4) deposited in offshore marine outer and inner shelf depositional environments. The Lower Maastrichtian strata are characterized by dark grey argillaceous, occasionally finely sandy biomicritic limestones with minor amount of glauconite and pyrite. The basal part, which rests directly on the Lund Sandstone, is frequently very sandy and less argillaceous. Calcareous and argillaceous beds comprise much of the Middle Maastrichtian, while the upper Middle Maastrichtian in the Lund area is locally composed of the approximately 50 m thick coarse clastic Hansa formation (Erlström & Larsson in prep.). This formation has, so far, only been encountered in the borings in the Lund area and in MO-1 (Fig. 2), where it underlies the 150-200 m thick Upper Maastrichtian chalk. The chalk sediments consist of whitish to creamy, occasionally light grey biomicritic limestones frequently interbedded with grey marl. Chert occurs as nodules and thicker bands irregularly spaced throughout the sequence, however, with some pronounced enrichment approximately in the upper 50-100 m of the formation.

The presence of Danian sediments has only been proved in some of the borings. However, in the Kyrkheddinge area it has been found to comprise approximately 80 metres of light grey, somewhat argillaceous and micritic bryozoan limestones, which frequently become silica cemented and hence well indurated. Chert occurs mainly as approximately 10 to 50 cm thick bands spaced irregularly in the sequence. Marly layers occur relatively frequently as interbedded units.

## BIOSTRATIGRAPHY

The first biostratigraphical investigation of the Lund Sandstone was performed by Brotzen (1942) on material from the Hilleshög-1 boring situated just north of Landskrona. The foraminiferal fauna indicated an Upper Cretaceous affinity of the sandstone. *Gavelinella costata*, *Cibicides* cf. *complanata*, *Globorotalia* n. sp. and *Bolivina delicatula* give a more precise Upper Campanian or Lower Maastrichtian age of the uppermost part of the sampled section at Hilleshög-1. In 1945 Brotzen presented a more detailed biostratigraphical zonation of the Campanian on material from the Höllviken-1 borehole, situated in the central part of the Danish Subbasin. Distinction from underlying Santonian strata is here based merely on the disappearance of the Globotruncana species. The Lower and Upper Campanian foraminiferal biozones are distinguished from each other by means of differences in the foraminiferal assemblage which also includes foraminifers with Maastrichtian range zones, in addition to characteristic species such as *Reusella pseudospinulosa* and *Gavelinella costata*. Also in Höllviken-1 the Upper Campanian is characterized by a typical Upper Cretaceous composition of the foraminiferal fauna with species ranging over several stages (Brotzen 1945).

Norling (in Ringberg 1976) performed complementary foraminiferal investigations on the Lund Sandstone in the Landskrona area on material from shallow borings at Asmundtorp, Billeberga and S. Möinge. His investigation demonstrated a Late Santonian to Early Campanian age by the findings of *Conorbina martini*, *Gavellinella pseudoexcolata*, *Bolivinoides strigillatus* and *Stensioeina labyrinthica*.

Biostratigraphical investigations of the Lund Sandstone were also performed on material from NV-1, BA-1, MO-1, KY-1 and KY-4. In MO-1 the interval 570-767 m below surface corresponds to the Upper Campanian according to the findings of *Neoflabellina rugosa* and *Stensioeina pommerana*. The upper boundary of the Lower Campanian is based on the disappearance of *Gavelinella clementiana*. This species is in MO-1 commonly occurring throughout the Lower Campanian, from 767 m down to 937 m. In MO-1 the Santonian-Campanian boundary is based on the last occurrence of *Archaeoglobigerina bosquensis* (Gabrielson in Chatziemmanouil et al. 1981; Fig. 6).

Only a preliminary biostratigraphical control has been obtained from samples between 730 and 780 m in NV-1, corresponding to the Lund Sandstone

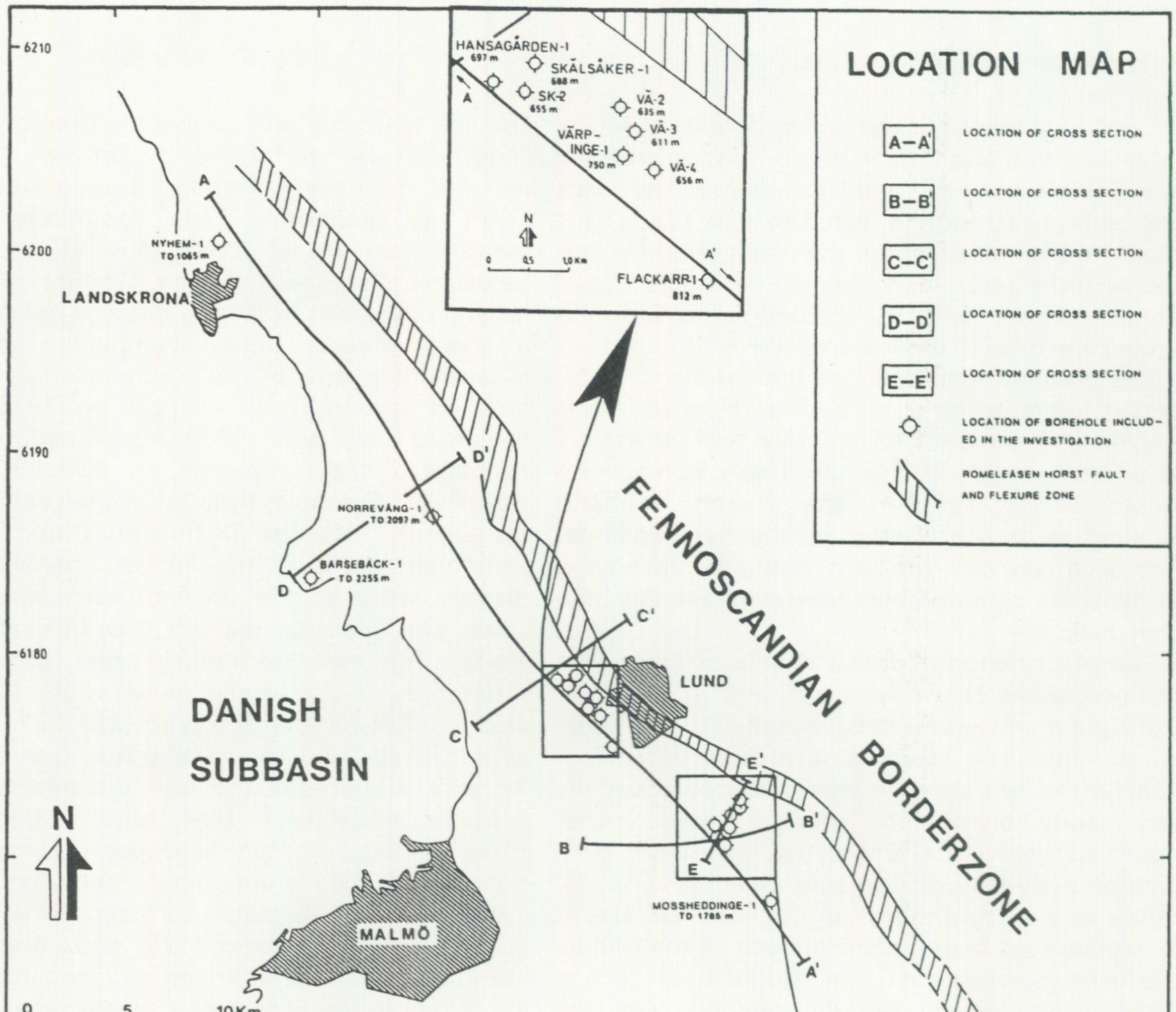


Fig.5. Location map of the investigated area with the location of the cross-sections.

(Holland & Gabrielson in Chatziemmanouil et al. 1981). The foraminiferal composition is Lower to Upper Campanian. Most of the identified species have wide ranges over several Upper Cretaceous stages. However, four of the species found are biostratigraphically important, i.e. *Stensioeina pommerana*, *Stensioeina exsculpta gracilis*, *Gavelinella pertusa* and *Bolivina incrassata*.

The most recent investigation was performed on material from KY-1 and KY-4 (Gabrielson in Cherns, Larsson & Thoregren 1983; Cherns, Erlström & Gabrielson 1983).

The Campanian age in these borings is mainly indicated by the occurrence of *Cibicides excavata* which does not range into Maastrichtian strata. *Neoflabellina rugosa* is a strictly Campanian species found commonly throughout the sequence between 435 and 837 m in KY-1 (Fig. 6). Santonian strata are found in the basal 5 m of the borehole. Typical Santonian species include *Globotruncana pseudolinneana* and *Stensioeina e. exsculpta* (Fig. 6).

Maastrichtian and Campanian strata in KY-4 are somewhat more difficult to distinguish since *Cibicides excavata* occurs at a depth of 480 m. However, *Gavelinella clementiana* is already present at 410 m, which gives a Campanian age at this level. Taking into account the clearly Maastrichtian fauna, e.g. *Cibicides complanata* and *Pseudovalvulineria gracilis*, found at 404 m the Maastrichtian Campanian boundary must occur in the interval 404-410 m.

Early Campanian and Santonian index species were not found in the KY-4 borehole (Cherns, Erlström & Gabrielson 1983).

It can be concluded that the Lund Sandstone ranges from the uppermost Santonian up through the Campanian. Beside on biostratigraphical data from KY-1 a Santonian age of the basal part of the formation is implied by the occurrence of sandstone beds over 250 m deeper in KY-6 and KY-7 than in KY-1. These beds are in lithofacial continuity with overlying beds and thus interpreted as belonging to the Lund Sandstone.

A late Santonian to Campanian age of the Lund Sandstone was also supported by microfossils found in material from shallow borings in the Öresund area between Helsingör and Helsingborg (Bang in Larsen et al. 1968).

Fossil groups other than foraminifers have not yielded any additional biostratigraphical information. Ostracode investigations performed on material from KY-1 (Sivhed in Cherns, Larsson & Thoregren 1983) yield merely an imprecise Upper Cretaceous age of the fauna. This is mainly due to incomplete knowledge on Campanian index species in the province and by the fact that Upper Cretaceous ostracodes commonly range over several stages.

## Descriptions of the borings

### GENERAL

#### The Kyrkheddinge area

The seven borings are all located in the surroundings of the Kyrkheddinge village approximately 10 km SE of the town of Lund (Fig. 5). These borings were drilled more or less along a traverse running perpendicular to the strike of the Romeleåsen Horst. The traverse is also more or less coincident with the seismic line S4 (cross-section E-É in Fig. 5; Fig. 34). The maximum distance between borings in the area is approximately 2 km. This offers a good opportunity to characterize the lateral variations in lithology, facies, and correlation of different units. All borings, except KY-4, have been drilled with slimhole technique, i.e. drilled with smaller diameter equipment than normally used. The hole size varies between 110 and 42 mm. The amount and size of retrieved cuttings is therefore less than in conventional rotary-drilling, with resultant difficulties to observe and describe the different lithologies properly.

Cores were taken in KY-1, -2, -3, -4, -5, and -6. However, most complete coring was carried out in KY-1 in which a total of 207 metres core was cut of which 127 metres was recovered. The other borings have only minor amount of cored sections. Cuttings were collected on an average every three metres within the penetrated part of the Lund Sandstone.

Preliminary descriptions of the cores and cuttings were performed at the well-site by geologists from the Swedish Geological CO. Data were subsequently compiled into well-site reports from each borehole (Cherns et al. 1983; Cherns and Erlström 1983; Erlström and Hesselbom 1984). These reports, together with complementary descriptions of cuttings and cores, constitute the base for the lithological

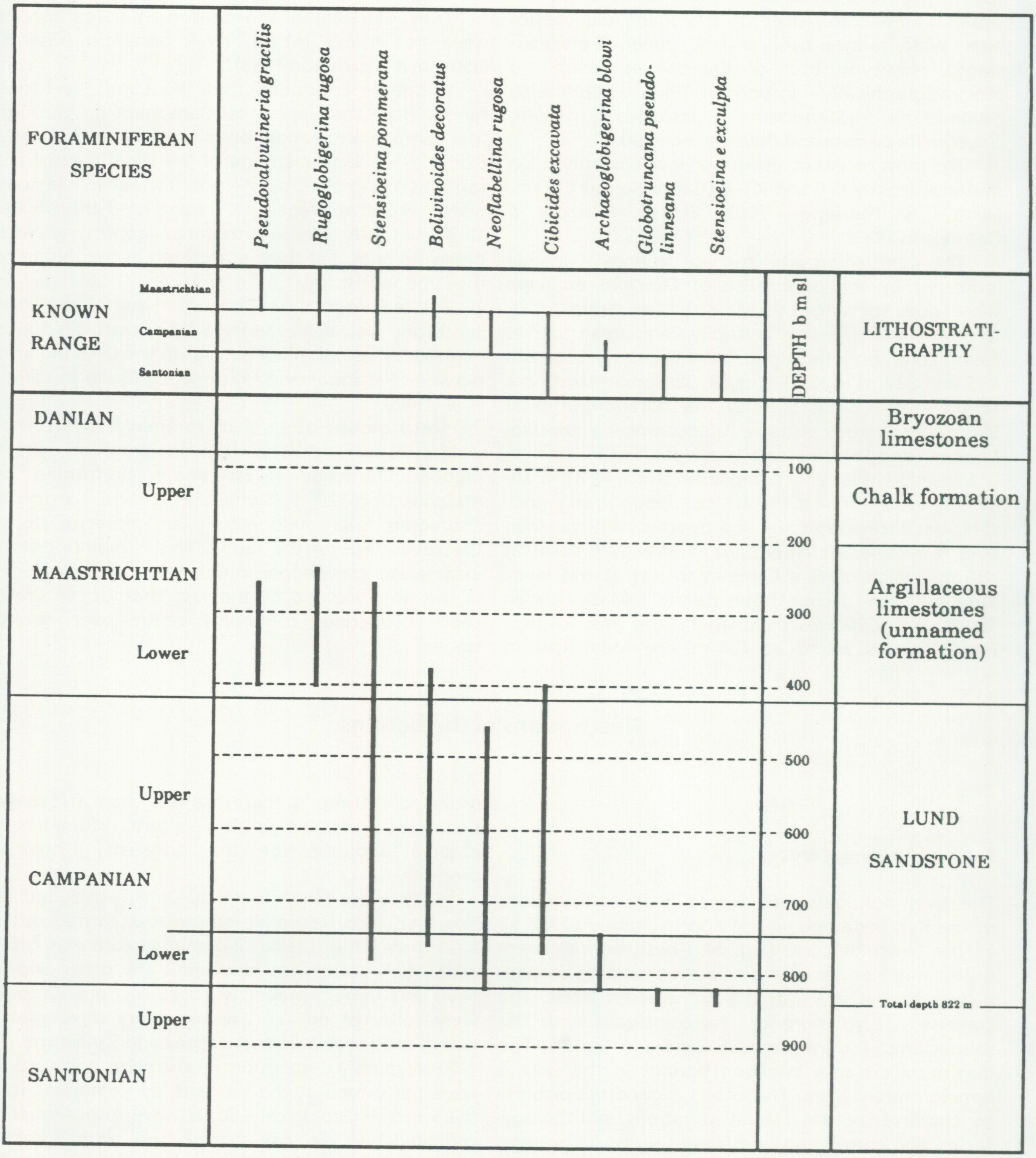


Fig. 6. Schematic illustration of the litho- and biostratigraphy in Kyrkheddinge-1 and the separate range of the different index foraminifers

descriptions presented in the Appendix.

The Lund Sandstone is very heterogeneous with regard to bed thickness. Intervals of sand/sandstone being thick in KY-2 and KY-7 decrease significantly in thickness to the SW. Thus, in KY-3 only fractions of the corresponding intervals are found. The dip of the Lund Sandstone increases to the NE, towards the Romeleåsen Fault and Flexure Zone. Thus, in KY-3 the dip is 2-5°, while in KY-2 it is 12-15°. Another striking difference between the borings is the lateral change in lithological properties, e.g. coarse sands grade into fine-grained beds or wedge out. This wedging-out of the coarse clastic members results in the overall decrease in thickness of the Lund Sandstone to the SW.

The sands are also commonly replaced by more calcareous sediments with varying content of argillaceous and arenaceous material in a SW direction. Thick beds of coarse sand are found mainly in the area just SW of the Romeleåsen Fault and Flexure Zone, i.e. in KY-2, -7 and KY-6. There the argillaceous component is generally low in the limestone members while it is significantly higher in the more distal borings in the area, i.e. KY-3 and KY-5. The limestones in the additional Kyrkheddinge borings are somewhat intermediate in character.

There is a frequent alternation between limestones and sandstones in the lower part of the formation, i.e. generally below 600 metres b.m. s.l. in the area. This feature seems to be more pronounced as one approaches the distal area in the SW. Since most of the borings in the area are situated along a section perpendicular to the Romeleåsen Horst (Fig. 5), the section permits a characterization of proximal and distal lithofacies. This characterization is also facilitatated by a more or less coincident seismic line, S4, which gives valuable information concerning formational dip and intraformational correlation. The characterization and correlation of the different lithofacies and depositional interpretation of the formation will be presented in subsequent chapters.

### The Lund area

During the years of 1982 to 1985 a total of eleven borings were drilled in the southwestern vicinity of the town of Lund. The geothermal system, operated by the Lund town council, includes four production, four injection and three observation borings, located within a relatively small area and with a small lateral spacing between the borings. The maximum distance is less than 2 km, which is the largest distance between borings in the area, i.e. between FL-1 and HA-1. Furthermore, HA-2, VÄ-5 and -6 are deviated borings drilled out of the same well head as a corresponding vertical well, i.e. HA-1 and VÄ-4. The wells included in this study were chosen for their position along an imaginary line of approximately 4 km long from FL-1 to HA-1.This line includes VÄ-4, Skälsåker-1 (SK-1), SK-2 and VÄ-1, VÄ-2, VÄ-3 beside the two end-wells. None of the wells penetrates the Lund Sandstone completely, since all wells are slightly shallower compared with borings in the Kyrkheddinge area. FL-1 is the deepest borehole with a total depth of 802 m in the Lund area.

The geological data from the borings in the Lund area are not as substantial as in the Kyrkheddinge area. This is mainly caused by the absence of cores. Thus, only 1.5 m of cores were recovered in FL-1 and SK-1. The geophysical logging operations were also of limited extent and of varying quality. The upper 100-150 metres of the Lund Sandstone have generally not been logged since this was not the target section of the geothermal prospecting. Data from the different wells referred to in this study were collected from various well-reports (Andersson et al. 1983; Andersson & Landberg 1984; Mari-Ripoll 1984; Erlström & Eriksson 1985a,b).The lithological descriptions have frequently been reevaluated and corrected according to information obtained from more detailed lithological analyses on cuttings and geophysical logs, during the course of this investigation. Compiled lithological descriptions are presented in the Appendix, starting with FL-1 and continuing northwestward with VÄ-4, -1, -2, -3, SK-1 to HA-1.

### Nyhem-1

The aim of this drilling being to investigate the Campanian aquifer and evaluate the geothermal capacity, geochemistry and hydraulic properties. No cores were cut.

This means that the lithological description was merely based on well-site descriptions of cuttings and interpretation of the available geophysical well logs which include sonic, caliper, single point resistance and gamma ray measurements. The description of the lower members of the Lund Sandstone in the interval below 780 m are described only from cuttings and from data from a caliper measurement.

### Norrevång, Barsebäck and Mossheddinge borings

These borings were all drilled by OPAB during the years of 1971-73. Norrevång-1 is situated approximately 10 km from the Romeleåsen Fault and Flexure

Zone. Barsebäck-1 is located 7 km WSW of NV-1. Generally, geophysical well logs correlate well between both borings. The borings penetrate the whole sedimentary sequence in this part of the Danish Subbasin, including Tertiary to Triassic strata before entering the crystalline basement at 2071 and 2176 m below mean sea level, respectively.

The Upper Cretaceous of NV-1 and BA-1 is characterized by more or less argillaceous limestones except for the Cenomanian sandstone and the Campanian Lund Sandstone. The mainly sandy strata of the Lund Sandstone Formation are found between 460 and 500 metres in BA-1 and 738-801 in NV-1. In addition to dominantly sandy strata these strata consist of arenaceous and argillaceous limestones. The lower part of the Formation is in BA-1 and NV-1 composed of mainly silty marls and marlstones.

Mossheddinge-1 is situated in the SE part of the investigated area. It penetrates Tertiary to Triassic strata before entering the crystalline basement at 1785 m. The Lund Sandstone is interpreted to make up the part between 580 and 890 m. The formation is mainly composed of quartzose medium-grained sands interbedded with argillaceous limestones.

#### Svedala-1

The penetrated sediments consist of a thick Upper Cretaceous sequence composed of mainly argillaceous limestones (90-1450 m).The interval 693-717 m corresponds to the Lund Sandstone (Chatziemmanouil et al. 1980). The Lund Sandstone is composed of mainly fine-grained beds of sand with intercalations of argillaceous and calcareous sediments.

## Petrology

The Lund Sandstone is characterized by frequent vertical and lateral changes in lithofacies. The heterogeneous lithology consists of dominantly siliciclastic deposits alternating with more or less fine-grained clastic-rich limestones. The bed thickness is generally 0.5-1.0 m. However, many individual beds are less than 0.5 m. The petrographical analyses show that four main lithofacies can be distinguished, i.e. quartzose sandstones, calcareous sandstones, arenaceous limestones and argillaceous limestones. There occur several minor petrographical variations within each main lithofacies. This has to be considered in the presentation of each facies.

The variation most commonly affects the amount of accessory minerals, cementation, fossil content and chemical composition. Occasionally intermediate lithologies occur, especially between the calcareous sandstones and arenaceous limestones. In such cases the distinction between facies is based on a comparison of the silica content of the investigated samples.The comparison of silica content has beenfound to be a useful instrument to group the four lithofacies. Thus the quartzose sandstone has a silica content of >80%, the calcareous sandstone 60-80%, the arenaceous limestone 40-60% and the argillaceous limestones are found to have a silica content of less than 40%.The grouping and characterization of the lithologies are based on the chemical analyses of 50 core samples, 200 petrographical analyses of porosity and bulk density, and also on thin section investigations, geophysical logs, grain size and microscopical investigation of cuttings and cores.

### THE QUARTZOSE SANDSTONE FACIES

This facies is found to occur throughout the Lund Sandstone. The beds are usually thin, normally less than 1 m. The beds are generally poorly cemented and composed of medium to coarse-grained mono- and polycrystalline quartz. However, the sandstones are occasionally well cemented and indurated by amorphous silica and/or blocky sparite (Fig. 7). The silica cemented intervals are irregularly shaped . The silica cement is most likely the result of precipitation of silica-enriched solutions which percolated through the rock. The enriched solutions came most likely from argillaceous interbeds where due to compaction, a significantly higher amount of silica was soluble in the interstitial pore-fluids.

The cementation could also be caused by silica-enriched fluids rising from deeper lying beds where pressure solution takes place at elevated temperatures and pressures, e.g. Triassic and Jurassic sandstones.

The chemical analyses reveal the dominant silica composition of the facies. The additional carbonate content, found to vary between 0.7 and 4.1%, corresponds to the patchy occurrence of sparitic cement and occasional fossil shell fragments.

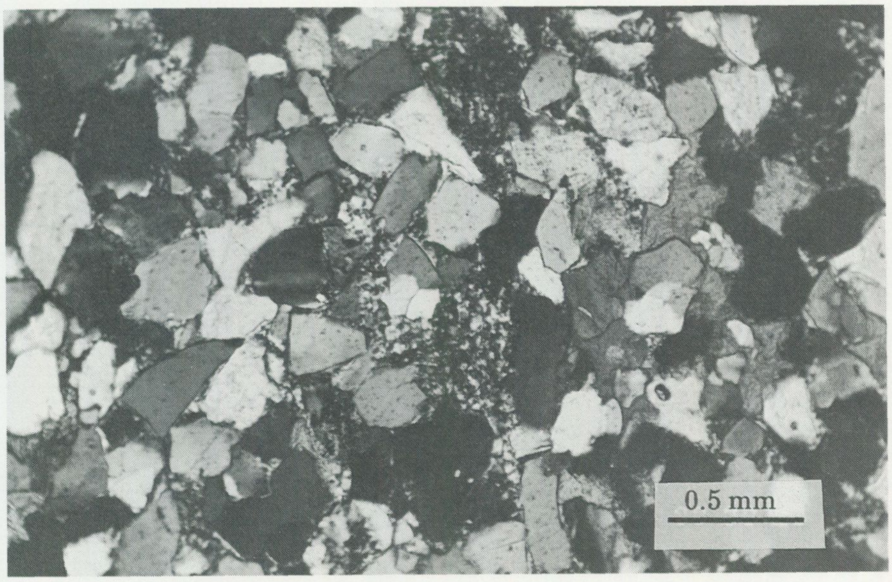


Fig. 7. Microphotograph of a quartzose sandstone sample from KY-1, X-nicols. SC: Silica cement.

The iron (2.08-3.32%), potash (0.26-1.64%) and aluminum (0.53-4.42%) are probably related to the minor amount of feldspars, crystalline rock fragments, clay minerals, mica and chamosite/glauconite found in various amounts as seen in the modal analyses.

The texture of the facies is characterized by subrounded or subangular detrital grains, mainly monocrystalline quartz, loosely packed with only tangen-tial or occasional long contacts between the grains. The sorting is generally very good as can also be seen by the uniform grain-size of mainly medium and coarse fractions. In the unconsolidated beds the porosity is relatively high being mostly greater than 25% and occasionally as high as 38% (Fig. 8). Indurated beds by either cemented silica or calcite have been found to have the lowest measured porosities of the four different characterized facies, commonly less than 10% but in many cases less than 5%. The permeability conditions of these indurated beds indicate a tight texture of the rock, especially for the silica cemented beds. The permeability is here very low being less than $10^{-3}$ mD (milliDarcy), corresponding to the encircled area A in the porosity/permeability cross-plot (Fig. 8). The area G in the same figure relates to the loosely packed counterpart of the same facies having significantly greater permeabilities with values greater than $10^3$ mD. A comparison of the bulk density and the porosity also yield similar grouping of the data for the different lithologies.

## THE CALCAREOUS SANDSTONE FACIES

This sandstone facies is dominantly cemented with sparite. However, frequently the cement is microsparitic (Fig. 9). The silica content is significantly lower, being 60-80% in the chemically analyzed samples and approximately 40-60% in the modally analyzed samples.

The fabric is generally denser and more complex compared with the quartzose sandstones, displaying a fine to coarse-grained texture of the rock. The skeletal component is occasionally as high as 14%. It is composed mainly of debris material from branched bryozoans, foraminifers, bivalves, echinoderms and brachiopods. Occasional ostracodes are also found.

In some of the investigated samples the amount of matrix is relatively high (20-40%) and composed almost exclusively of synsedimentary biomicritic mud. The detrital components are frequently floating in the matrix, thus having very few contacts with each other. The contacts observed are seldom of long or concave/convex type but most commonly of an edge to edge nature.

The glauconite and chamosite components contribute significantly to the sediment composition in a number of investigated samples. On average 0.5 mm

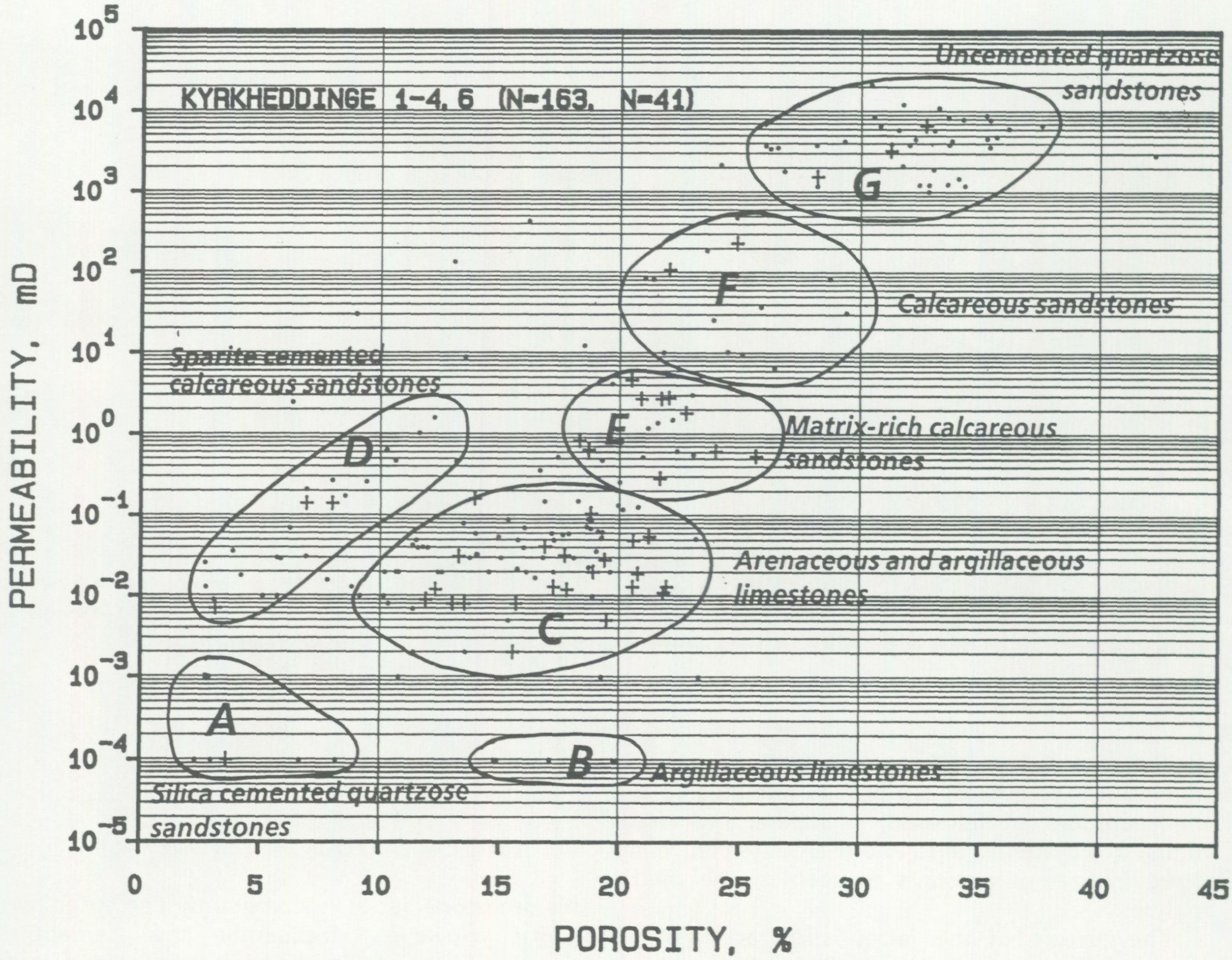


Fig. 8. Permeability and porosity cross-plot on core samples from KY-1, -2, -3, -4 and -6. The plot includes values from 163 horisontally and 41 vertically cut plugs.

large variably dense glauconite/chamosite grains occur in a detrital mode in the fabric and reach at some levels up to several percent of the bulk modal composition. The feldspars, which at some levels make up 4% of the bulk composition consist mainly of unaltered microcline and to a minor extent of plagioclase.

The poly-crystalline rock fragments consist almost exclusively of a mixture of quartz and feldspars. Other components such as mica, coal and opaque minerals occur in very small quantities, generally less than 1%. The opaque minerals, mainly authigenicpyrite and ilmenite, are common in some samples.

The calcareous content, which comprise on average 30-60% of the bulk, derives from three different components, i.e. biomicrite, sparite and skeletal debris. The sparite occurs either as intergranular blocky crystals or as single large crystals embedding the detrital grains in a poikiloblastic way (Fig. 10) in rather clean medium to coarse-grained loosely packed sands. The sparitic cementation has locally led to the complete filling of the previous voids and pores, thus producing a relatively well indurated sediment with low porosity which is shown in the encircled area D in figure 8, below approximately 10% and corresponding permeabilities of between $1\text{-}10^{-2}$ mD. The bulk density is somewhat lower than for the detrital rich sparite and silica cemented quartzose sandstones, being generally 2.4 to 2.5 g/cm$^3$.

The micrite-rich sandstones are also relatively well indurated. However, there are no major amounts of cement, beside a minor amount of fringing microsparite, e.g. in voids inside bivalve and brachiopod shells, in occasional samples. Here, the induration is instead caused by the cohesive nature of the fine-grained micritic matrix, composed of finely ground bioclastic material together with silt and clay. The bulk density of these sandstones varies thereby somewhat accordingto the amount of pure biomicrite in the sediment. Silty and poorly sorted beds have

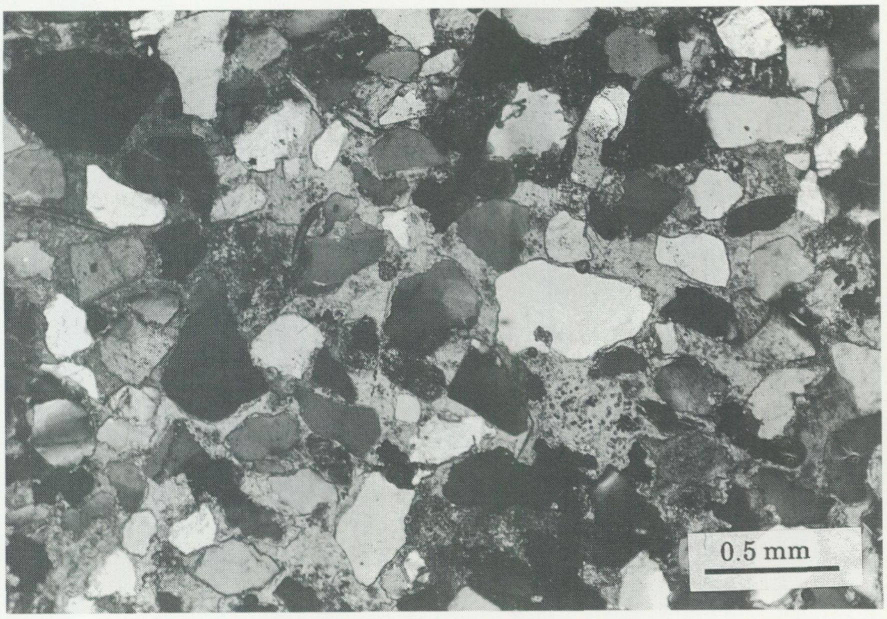


Fig. 9. Microtexture of the calcareous sandstone facies in a sample from KY-3. X-nicols.

relatively low densities between 2.1 and 2.2 g/cm$^3$.

The porosities and permeabilities of the micrite-rich sandstones are generally somewhat higher in the more detrital-rich samples due to larger amount of voids. Non-micritic matrix, such as clay in the sediment, decreases the permeability somewhat due to the corresponding low conductivity of clays and decrease of intergranular pores and voids. Thus, the calcareous sandstones have porosities between 20 and 30% and permeabilities of 10-300 mD (F in Fig. 8). An increasing amount of micritic matrix is found to cause a decrease in the permeability to 0.2-4 mD. The decrease in porosity is marginal (cf. encircled area E in Fig. 8).

The third calcareous component, the skeletal debris, varies from 0 to 14% in the investigated samples. Microfossils such as bryozoans, foraminifers and ostracodes constitute the main fossil groups represented. Larger fragments of broken shells from bivalves, brachiopods and echinoderms are rarely found.

The result from the chemical analysis of ten different calcareous sandstone samples from KY-1, -2, -3, -4 and -6 shows significantly higher silica content than what could be estimated from the modal analysis. This could only be explained by an underestimation of the silica content in the interstitial, non-calcareous matrix component.

The other chemically traced components do more or less coincide with the minerals observed in the thin sections (plagioclase, glauconite, pyrite, microcline, mica and different clay minerals). The carbonate content is found to relate strongly with the amount of $Ca^{2+}$ in the samples, but since some of the calcium ions also occupy sites in feldspars and clays one has to assume a corresponding decrease of the calcium carbonate content.

## THE ARENACEOUS LIMESTONE FACIES

The two sandstone facies described above are frequently interbedded with or alternate with less clastic-rich beds composed of either argillaceous or arenaceous limestones. The distinction between the different facies is occasionally diffuse.

The arenaceous limestone is characterized by a tight heterogeneous fabric of biomicrite, and by non-micritic matrix including clays. Further it contains organic material, fossils and variable amounts of detrital grains, mainly quartz, in a wide size-range from fine up to coarse fractions (Fig. 11).

The detrital component comprises between 18.1 and 46.1% in the modal analysis of 33 thin sections from cores from KY-1, -2, -3 and -4. The main part of the detrital component consists of fine-grained mono- and poly-crystalline subrounded quartz, irregularly occurring in the micritic rock. Detrital

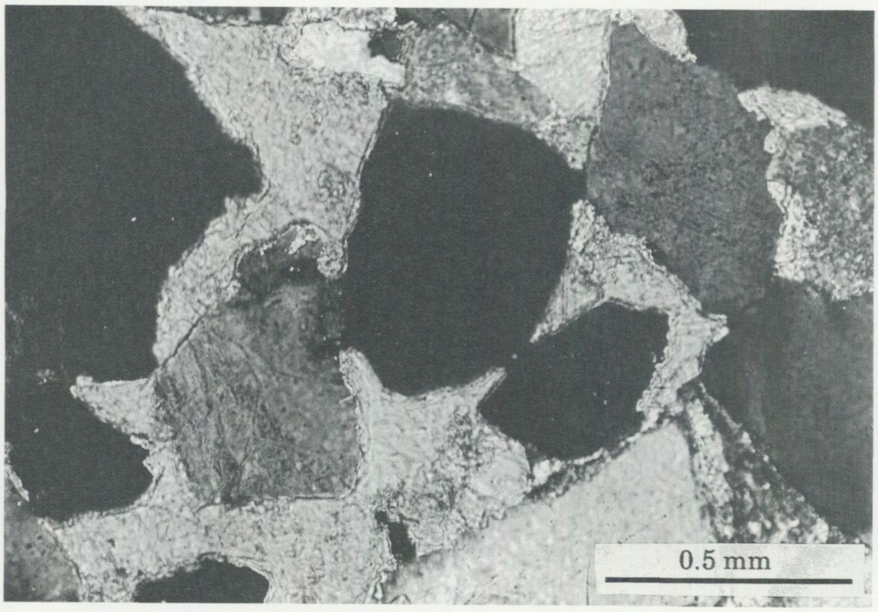


Fig. 10. Microphotograph of a calcareous sandstone sample from KY-1 showing the habitus of the sparite cement which encloses the detrital grains in a poikiloblastic way. X-nicols

grains are commonly enriched in irregular bands and semilenticular zones, which can be explained as the result of reworking of the sediment by bioturbation.

The feldspar component consists of microcline with a minor amount of plagioclase. It contributes only to a minor extent to the overall composition of the sediment, reaching an observed maximum content of 2.8%.

The organic content is very significant in some beds, e.g. KY-2, 775.5 m, where up to 10 mm long elongate coal particles occur more or less horizontally bedded (Fig. 12). Thin laminae of blackish minute particles are also frequent in some beds. Nevertheless, the organic content does not belong to the most characteristic components of the facies.

The single largest component is the matrix/micrite which on average contributes to more than 50% of the composition. In most cases it is impossible to distinguish microscopically between the siliciclastic and the bioclastic matrix. The relation is instead determined by comparing the $CaCO_3$ content from the chemical analysis, which gives on an average 37.2% carbonate compared with the $CaCO_3$ average from the modal analysis. There the carbonate is found in the sparite and skeletal debris groups as well as in the matrix. The groups comprise on average 65.9% of the sediment. This gives a matrix composed of approximately equal amounts of non-carbonate and carbonate material.

The clay content is frequently significant in the facies and occurs both as pore fillings and as wavy irregular subparallel laminae with thin semi-lenticular, more silty interbeds. The clay consists of smectite and kaolinite minerals as shown in the X-ray diffractogram from KY-1 (Figs.13-14). The smectite minerals dominate by the significant difference between the 14Å (001 smectite) and 7Å (001 kaolinite) peaks. The EG-treated samples show a swelling of the 001 smectite peak to approximately 17Å (Figs. 13-14). No other 14Å minerals such as chlorite were identified contributing to the un-treated 14Å peak. Additional identifiable minerals in the $<10$ µm fraction are minor amounts of hydromica, quartz, pyrite and feldspars.

The smectite clay minerals in the matrix are most commonly ordered in a typical honeycomb structure where edge to face attraction forces of the separate clay platelets cause the construction of a spongy cell-like micro-structure. Microfossils (foraminifers and ostracodes) are frequent in the lithofacies as are various shell debris from bivalves, brachiopods. Echinoderm debris is most common. Occasional concentrations of relatively well preserved echinoids have been found for instance in a core from KY-1. Small, $<5$ mm long, vertebrate teeth are rarely found. The amount of glauconite averages 1.1%, whichis lower than what has been found in the previous facies. However, it is plausible that the amount is underestimated due to small grain-size of


Fig. 11. Microtexture of the arenaceous limestone facies in a sample from KY-3. X-nicols

the glauconite particles and minute particles found in the micritic-sized matrix.

The opaque minerals are dominated by pyrite which most commonly occurs as centimetre sized nodules in more argillaceous beds.

The petrophysical analyses show that the clay content of the sediment has an important role upon development of the porosity and permeability conditions.

There seems to be a clear correlation between the occurrence of thin argillaceous laminae and the significant decrease of the vertical permeability. Most measurements indicate porosities between 10 and 20% (Fig. 8), identical to those of the argillaceous limestones.

This is most likely caused by the smectite clay minerals and their honeycomb microstructure yielding relatively high porosities. The permeabilities are, however, generally below 0.1 mD (Fig. 8) which again is probably caused by the character of the clay minerals and their ability to hold water.

Bulk density versus porosity displays the grouping of the arenaceous limestone facies with densities between 2.25 and 2.45 g/cm$^3$ and with corresponding porosities of 10 and 20%.

## THE ARGILLACEOUS LIMESTONE FACIES

This facies occurs frequently throughout the Lund Sandstone as thin interbeds in connection with fine-grained sandstone intervals and as more uniform beds up to several metres thick. The argillaceous limestones most commonly occur in connection with arenaceous limestone beds and occasionally are very similar in character, although, less rich in silica.

The texture of the facies is characterized by sub-angular fine and very fine-grained detrital grains of quartz and occasional feldspars (microcline) supported by a dominant amount of slightly brownish coloured argillaceous biomicritic matrix (Fig. 15).The texture is frequently patchy due to variation of silt-sized and very fine-grained quartz and more clay-rich lenses. This patchiness is most likely produced by bioturbation. Wavy thin subparallel and irregularly spaced lamination of clay and organic material is also commonly found (Fig. 15).

The average non-carbonate detrital components, mainly quartz are 15.0% in the point-counted thin sections (Table 1). This is far less than the average from the chemical analysis (Table 2). Only for the silica part (Table 2) the average amount is 32.8%, or 37.7% if one also include the average sums for $Al_2O_3$ and $Fe_2O_3$. These last two components have beside $SiO_2$, CaO and $CO_3$ the highest average weight percentages. The discrepancy is caused by the minute clay fraction which comprises a significant part of the matrix.

The calcium carbonate content of the facies averages 50.6% according to the chemical analyses

Table 1. The average modal composition of the four main lithofacies identified herein.

| FACIES / GROUP | QUARTZOSE SANDSTONE | CALCAREOUS SANDSTONE | ARENACEOUS LIMESTONE | ARGILLACEOUS LIMESTONE |
|---|---|---|---|---|
| VOID | 13.5 | 1.3 | 0.1 | 0.1 |
| MATRIX | 1.3 | 11.3 | 55.3 | 74.3 |
| DETRITAL | 71.4 | 52.1 | 30.3 | 15.0 |
| SPARITE | 3.7 | 27.2 | 0.5 | 0.2 |
| FELDSPAR | 3.2 | 1.4 | 0.6 | 0.1 |
| SKELETAL | 1.4 | 3.8 | 10.6 | 9.3 |
| COAL | 0.2 | 0.1 | 0.8 | 0.1 |
| OP. MINERALS. | 0.1 | 0.6 | 0.6 | 0.7 |
| MICA | 0.2 | 0.1 | 0.1 | 0.1 |
| GLAUCONITE | 5.0 | 2.2 | 1.1 | 0.3 |
| TOTAL | 100.0 | 100.1 | 100.0 | 100.2 |

Table 2. The average chemical composition of the four main identified lithofacies.

| FACIES / ELEMENT | QUARTZOSE SANDSTONE | CALCAREOUS SANDSTONE | ARENACEOUS LIMESTONE | ARGILLACEOUS LIMESTONE |
|---|---|---|---|---|
| $SiO_2$ | 84.7 | 66.4 | 47.6 | 32.8 |
| $TiO_2$ | 0.3 | 0.4 | 0.3 | 0.3 |
| $Al_2O_3$ | 1.9 | 4.0 | 2.8 | 2.9 |
| $Fe_2O_3$ | 2.9 | 2.8 | 2.1 | 1.9 |
| MgO | 0.2 | 0.7 | 0.6 | 0.7 |
| CaO | 4.3 | 10.7 | 21.5 | 29.0 |
| $Na_2O$ | 0.3 | 0.5 | 0.2 | 0.2 |
| $K_2O$ | 0.8 | 1.2 | 0.8 | 0.8 |
| $P_2O_5$ | 0.1 | 0.1 | 0.1 | 0.1 |
| $CO_3$ | 4.1 | 11.1 | 22.3 | 30.4 |
| S | 0.1 | 0.6 | 0.3 | 0.3 |
| Other elements | 0.7 | 1.3 | 1.5 | 0.6 |
| **Total** | 100.3 | 99.8 | 100.2 | 100.0 |

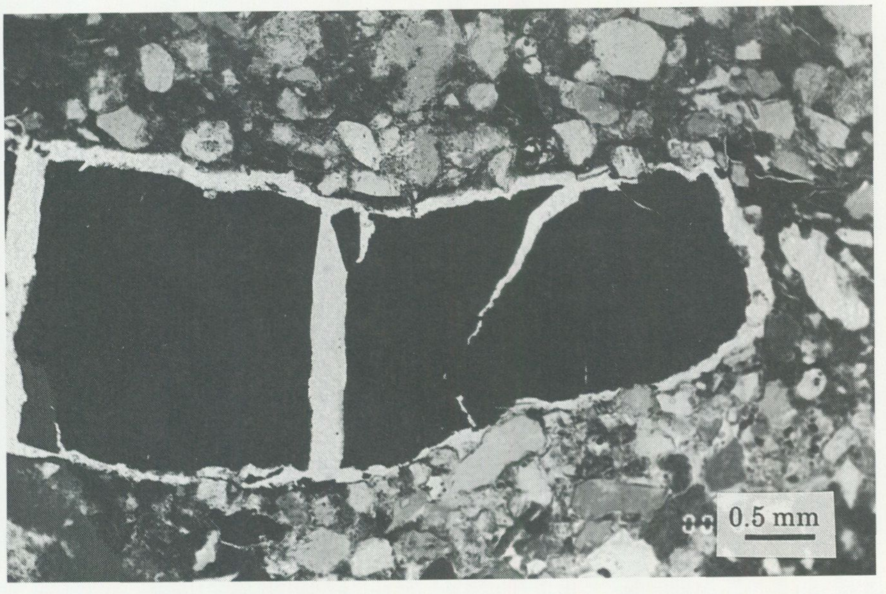


Fig. 12. Microphotograph of a detrital coal fragment. X-nicols.

It is more difficult to obtain a comparable figure from the modal analysis. In the latter only 9.5% of the material consists of observable carbonate, i.e. skeletal material and sparite. There is therefore, in addition a significant amount of micritic carbonate in the matrix of the sediment. This amount is estimated by comparison with the chemical analysis. A non-carbonate content of 38.4% ($SiO_2$, $Al_2O_3$, $Fe_2O_3$, $Na_2O$, $K_2O$; Table 2) subtracted by the amount of observed quartz (15.0%;Table 1). The remaining 23.4% is then subtracted from the matrix (74.3%; Table 1) which results in a carbonate content in the matrix of 50.9%. On adding the average for fossil skeletal and sparite content (9.3 + 0.2%; Table 1), the result is slightly higher (60.4%) total carbonate content of the sediment as compared with the results from the chemical analysis.The non-carbonate in the matrix is composed of smectite and kaolinite clay minerals, minute quartz particles and a minor amount of hydromica (cf. X-ray diffractograms from KY-1, 675.4 m, 701.2 m, 726.6 m and 737.6 m and 795.0 m; Figs. 13-14). Smectite-rich parts of the matrix has again, as for the previously described lithofacies, a spongy cell-like honeycomb microstructure (Fig. 16).

In addition to calcium carbonate and fine-grained quartz, there occur minor amounts of glauconite and opaque minerals in the lithofacies. The highest amount of glauconite (1.8%) is found in a sample from KY-1 (693.82-85 m). The highest amount of opaque minerals, i.e. pyrite, is found in KY-2 (751.31-34 m).

The argillaceous limestone is frequently very rich in microfossils, such as foraminifers, bryozoans and ostracodes. The amount of fossil skeletal material averages 4.3% (Table 1), which is comparable with the figure for the more arenaceous facies (Table 1).

Macrofossils such as bivalves, brachiopods and echinoderms occur in relatively small quantities of the total amount of skeletal material.

The petrophysical character is also quite similar to that of the arenaceous limestone. Thus, the bulk density ranges from 2.3 to 2.45 g/cm$^3$, and the porosity from 10 to 20% (Fig. 7). The permeabilities vary between 0.1 to $10^{-3}$ mD, occasionally down to $10^{-4}$ mD when the argillaceous content of the sediment is significant (B in Fig. 8).

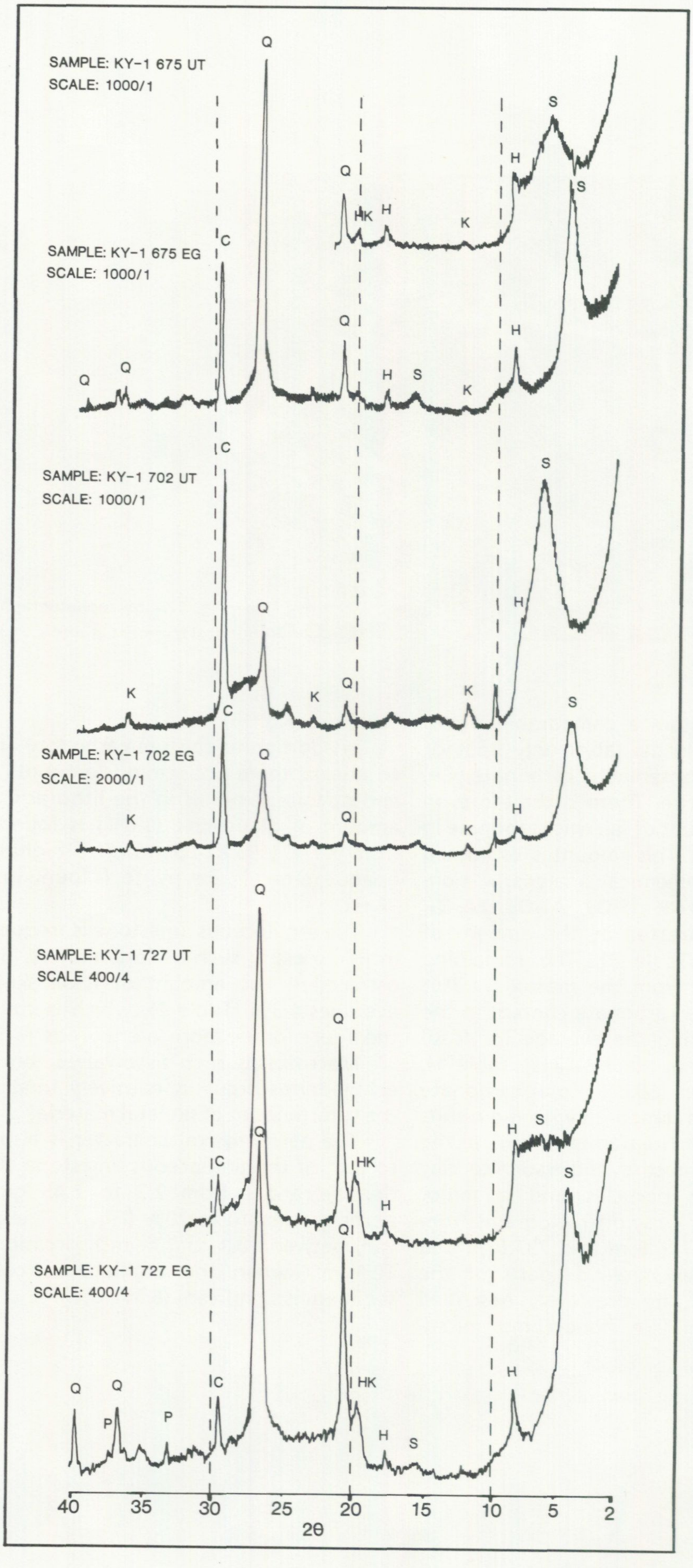


Fig. 13. X-ray diffractograms on arenaceous and argillaceous limestone samples from KY-1.

S: Smectite, K: Kaolinite,
H: Hydromica, Q: Quartz,
C: Calcite, P: Pyrite
HK: Smectite diffraction bands
EG: Ethylene glycolated.
UT: Untreated.

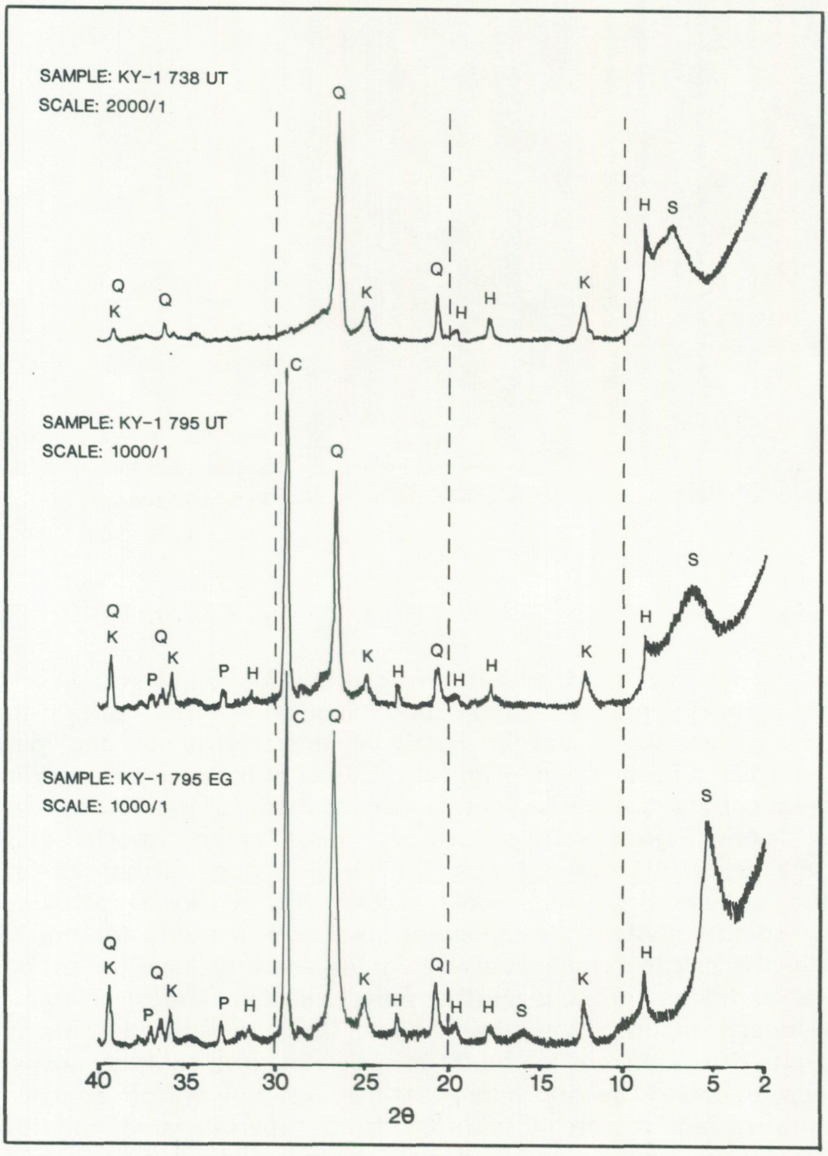


Fig. 14. X-ray diffractograms on arenaceous and argillaceous limestone samples from KY-1.

S: Smectite, K: Kaolinite,
H: Hydromica, Q: Quartz,
C: Calcite, P: Pyrite
HK: Smectite diffraction bands
EG: Ethylene glycolated.
UT: Untreated.

## Petrology of cement and authigenic minerals

Cement is absent in the main part of the sand/sandstone beds of the Lund Sandstone. However, some beds are occasionally well cemented with either calcite, silica or pyrite. These cements are also commonly found in conjunction with each other.

The cements are heterogeneous in appearance showing both vertical and lateral variation in amount and habitus. An irregular patchy occurrence is most common.

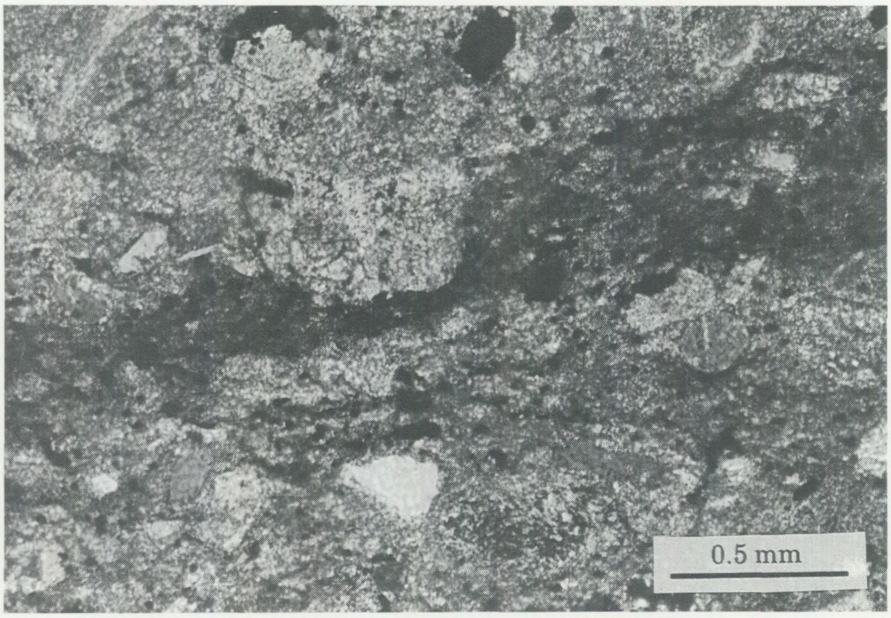


Fig. 15. Typical microtexture of an argillaceous limestone sample from the Kyrkheddinge area.

## CALCITE CEMENT

Sparite cement occurs most commonly in the quartzose and calcareous sandstone facies, mainly as blocky intergranular crystals. The average size of the calcite crystals varies from 0.2 to 0.5 mm, i.e. medium to coarse. Individual crystals frequently attain a size of up to several millimetres. These large crystals commonly envelope several smaller detrital grains, thus showing a poikiloblastic texture (Fig. 10). Contacts between the blocky sparite crystals are either straight or wavy. Locally the calcite cement enclose corrosion structures in an earlier amourphous silca cement around detrital quarts grains. Thus, circular to semicircular etched pits, 10-30 microns in diameter and a few microns deep, are found covering the surfaces of quartz grains in an irregular patchy manner (Fig. 17). The primary crystal surface beneath the few micron thick microcrystalline amourphous silica cover is seen at the bottom of some of the pits in figure 17 A. One explanation of these etched pits could be that alkaline solutions etched the silica cement prior to the calcite cementation. Fringing sparite is found especially in fossil-rich sandstones where the crystals fringe shell fragments and protrude into the interparticle voids which also may be filled with blocky sparite. Calcite cement is occasionally found together with silica and pyrite cements. The limestones are dominated by micro-sparite cement.

## SILICA CEMENT

Authigenic silica is found at various levels throughout the Lund Sandstone. The silica is present as intergranular microcrystalline and patchy cement (Fig. 18, 19). Most of the precipitated silica is found in loosely packed beds of quartzose and calcareous sandstones, most often associated with calcite cements. The silica does furthermore not originate from sources within the rock. This is evidenced by the apparent absence of pressure solution. The contacts between grains are almost exclusively point to point. Furthermore, the grains are often found floating in the cement. Thus, no sutured contacts have been found as a sign of silica solution. Instead it is more likely that the silica derives from enriched percolating solutions from supersaturated conditions in connection with compaction and dewatering of argillaceous beds within or outside the Lund Sandstone. Since these beds were originally more porous than the sands, they endured comparatively greater compaction than the latter. The argillaceous sediment may contain a higher than normal content of silica due to pressure conditions or transformation of smectite to hydromica with silica release. The compaction results in the percolation of silica enriched solutions into adjacent porous sands.

One good example of this is seen in a core sample from FL-1 (727.3 m; Fig. 20) where a porous thin irregularly shaped sand layer is found within a domi-

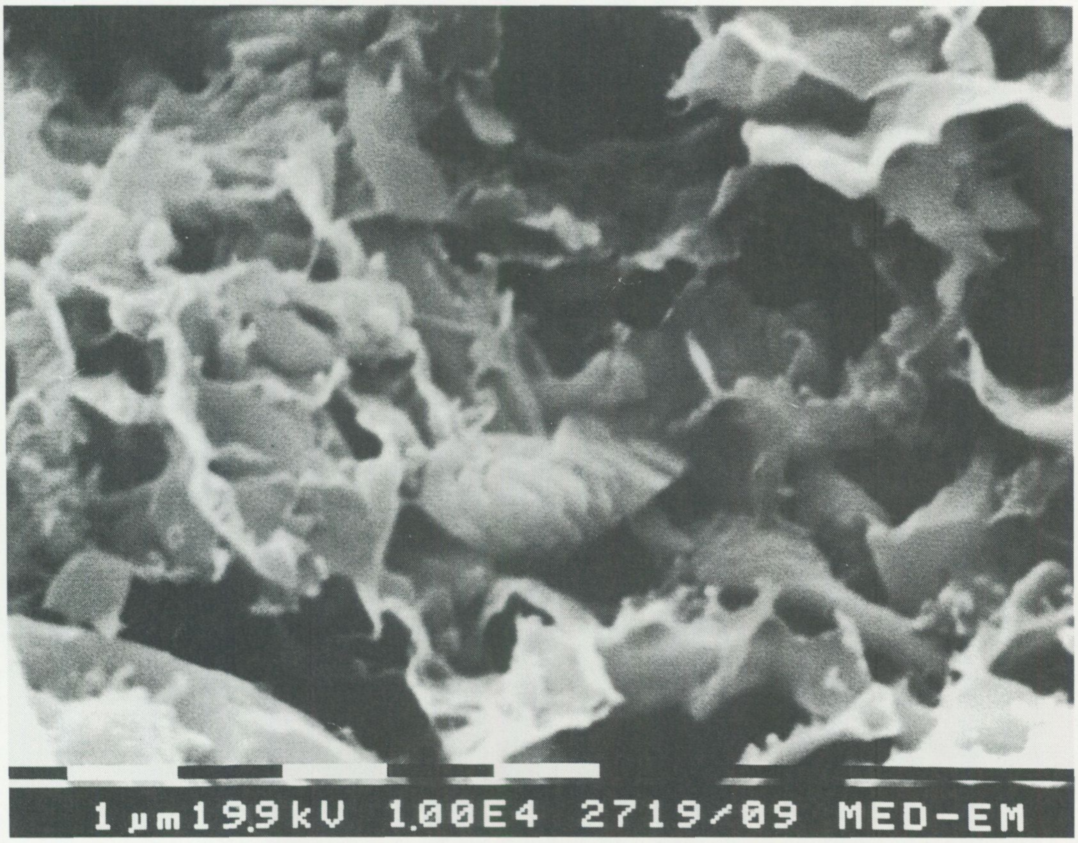


Fig. 16. Smectite honeycomb stucture in an argillaceous limestone from KY-4 (680 m).

nantly argillaceous bed. The sand layer is cemented with silica. Similar thin beds of silica cemented sands can be observed in core-material from e.g. KY-4 (Fig. 26).

AUTHIGENIC PYRITE

Pyrite is found in all lithofacies except in the pure quartzose sandstone beds.

Pyrite occurs most commonly in strongly argillaceous beds as nodules up to several centimetres in diameter. The nodules are composed of minute crystals (Fig. 21) which occur in some cases as fillings of intraparticle voids and occasionally as interparticle filling and thus being a cementing agent together with silica and calcite.

## Textural analysis of the unconsolidated sands

GRAIN-SIZE AND SORTING

Grain-size analyses of the detrital components of poorly indurated and unconsolidated sediments were performed on samples from the Lund and Kyrkheddinge borings. The analyzed sections are vertically spread through the Lund Sandstone in the various borings with consideration to the variation of available material and target interval for each specific borehole. Generally, samples have been analyzed from the lower part of the Lund Sandstone, i.e. for KY-1, -2, -3 and -4 below 600 m. The best information derives from these four borings (Fig. 22). In KY-6 and -7 only the deepest situated major sand intervals were analyzed.

Ten to fifteen samples from variably thick sand/sandstone intervals in seven borings in the Lund area were analyzed.

**Kyrkheddinge-1**

The grain size distribution (Fig. 22) is based upon thin sections from the cored intervals 661.4-819.5 m.

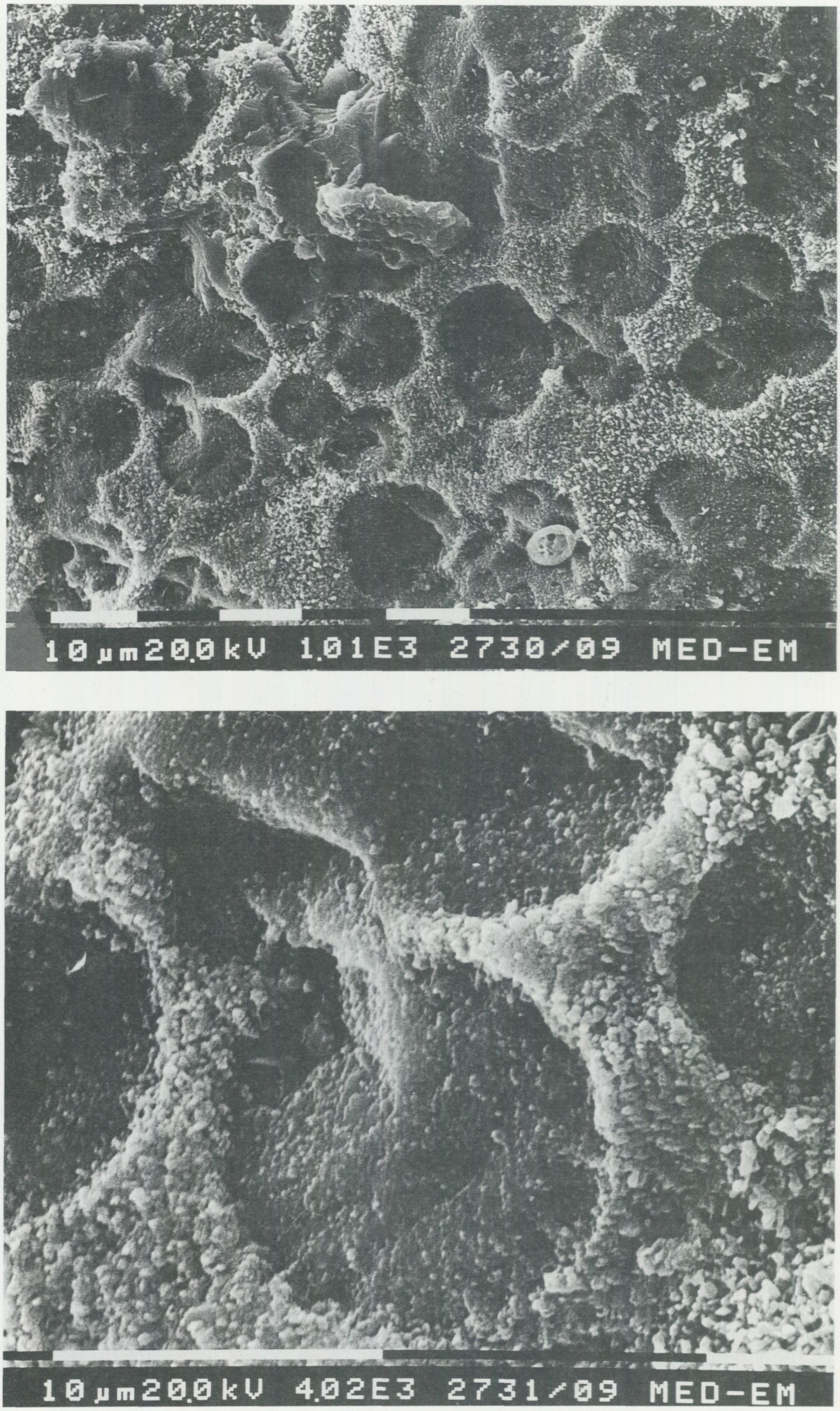


Fig. 17. A: Etched pits on the surface of a quartz-grain from a calcite cemented sandstone bed in KY-1. B: Close-up view of the same surface.

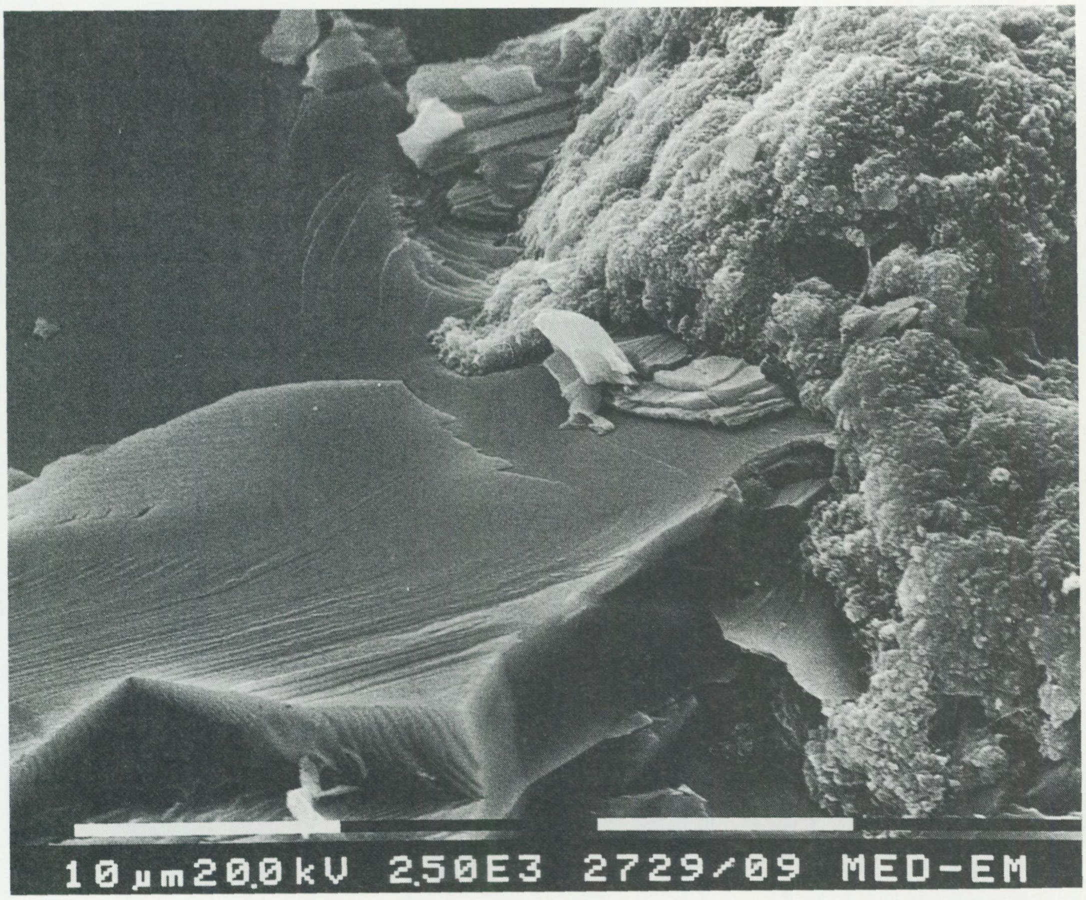


Fig. 18. Amorphous silica cement (SC) on a quartz-grain (QG) in a well indurated quartzose sandstone sample from 731 m in KY-1.

Major sand/ sandstone intervals occur at 700-711, 730-786 and 796-819 m. These are separated by argillaceous and arenaceous limestone units. The sands are dominantly fine to medium-grained, with angular to subrounded, milky or vitreous quartz-grains having low to moderate sphericity. Furthermore, a high proportion of the sandstones are loose or poorly consolidated.

**Kyrkheddinge-2**

Results from a sieve analysis carried out on cuttings from the interval 604-865 m are shown in figure 22. Since these data refer to 3 m intervals they represent mixed sediment and are therefore approximate. However, they are adequate enough to illustrate the overall distributional features, such as the dominant size fractions and the clay/silt/sand ratios.The amount of plastic clay component in the samples is illustrated on the left-hand side of the size distribution graph. By comparison with the lithological log the clay fractions are generally smaller, which suggests some loss of finer material during drilling and the collection of cuttings. The clay content is low, commonly <5%, in the four clastic units present in the sequence covered. Generally the proportion of clay is somewhat greater in the argillaceous limestones, and the highest values (20-25%) correspond to samples which disaggregated only partially during sample pretreatments. The silt fraction, <0.07 mm, shows a similar distribution pattern, comprising < 8% in the sandstones but reaching up to 30% in singular beds interbedding the limestones.The sand grade material is split into five fractions: very fine (0.07-0.125 mm), fine (0.125-0.25 mm), medium (0.25-0.5 mm), coarse (0.5-1.0 mm) and very coarse (>1.0 mm). Medium sand forms the prevalent size-fractions in the sandstones, although fine sand is commonly also quantitatively important. Coarser fractions occur as major component in occasional beds. Coarser grains are present in appreciable amounts only at some levels in the thick sandstone member between 753 and 802 m. The very fine and fine size fractions form a greater proportion of the sand component in the limestone intervals.

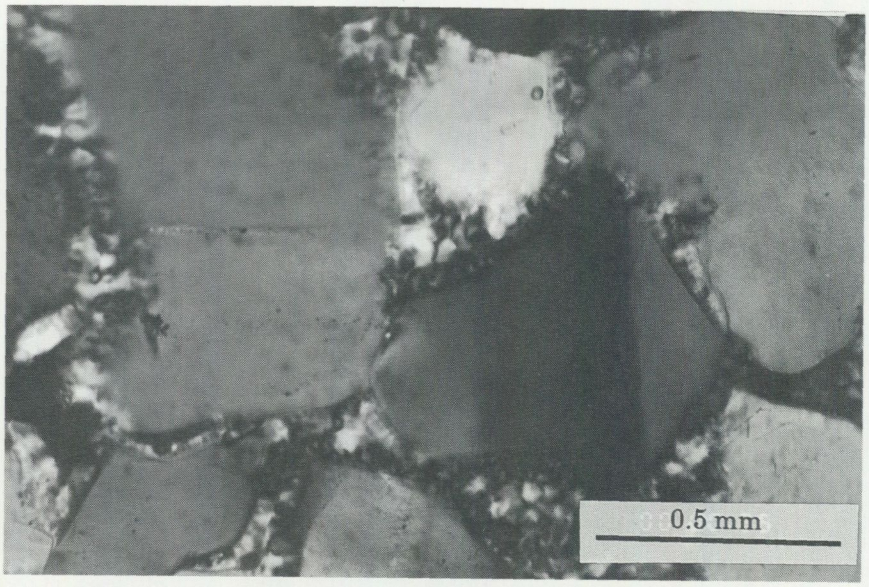


Fig. 19. Microphotograph showing the occurrence of siliceous cement in a quartzose sandstone sample from KY-2. X-nicols.


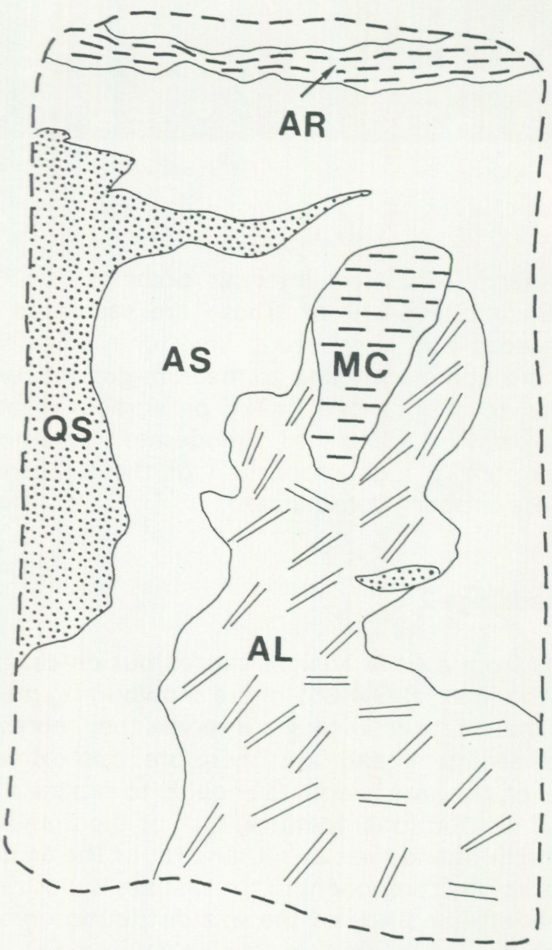


Fig. 20. A: Photograph of a well indurated silica cemented dewatering structure within a dominantly argillaceous limestone bed at 727.3 metres depth in FL-1. B: Schematic sketch of the same structure. QS: diapiric centrum of silica cemented quartzose sandstone, AS: disturbed zone of silty sandstone, AL: argillaceous limestone with scattered mudclasts (MC), AR: argillaceous laminae.

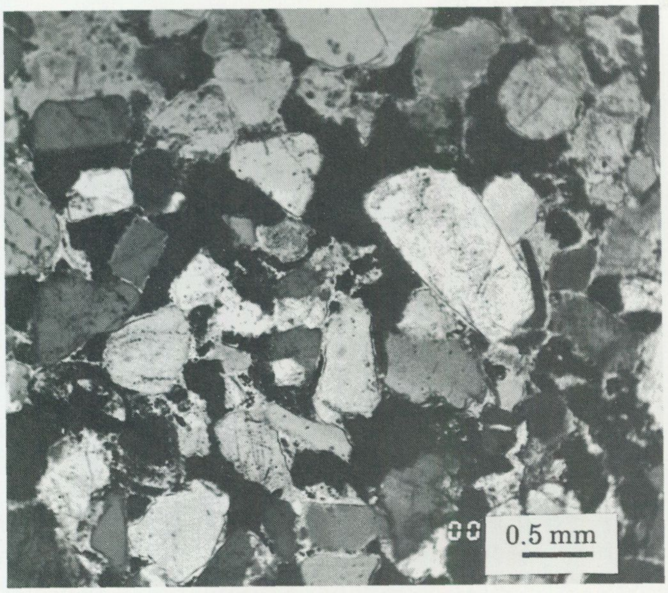

Fig. 21. Microphotograph of a pyrite cemented calcareous sandstone sample from KY-6. Nearly all of the pores in this photograph are completely filled with authigenic pyrite.

### Kyrkheddinge-3

The results from sieve analyses of cuttings from 3 m intervals through the sequence 586-869 m are compiled in figure 22. As noted for KY-2, these data represent mixed sediment and are therefore approximate. Some loss of finer material, and particularly the plastic clay component, has also occurred during drilling and collection of samples. The smaller fraction is therefore underrepresented in the size-distribution graph.

The results illustrate the major distributional features of the dominant size class and the variations in the clay/silt/sand ratios through the sequence. A number of samples from limestone intervals retain a significant proportion of aggregated particles. The remnant rock fragments, composed mainly of argillaceous and arenaceous limestone are merely found in the larger fractions, >0.25 mm.

The sandstone intervals have a relatively low clay content, commonly < 10%. The clay component is generally higher throughout the sequence than in KY-2, and notably higher than in KY-1.

Sandstone samples contain <10% silt on an average and several levels contain less than 1-2%, e.g. 800-803 m and 824-848 m. The silt content is generally higher in the limestones, on an average >30%, e.g. 586-604 m (31%), 722-725 m (36%), 740-743 m (32%). As for KY-2 the sand grade material is separated into five classes. In the higher clastic interval between 649 and 692 m the dominant size fraction among the sandstones is medium sand. The major lower clastic units between 768 and 838 m contain fine sand which exceeds or matches the medium sand component. This contrasts with the continuing dominance of medium sand through the investigated KY-2 sequence. There is also a comparatively small amount of coarse sand material in the samples as compared with the latter borehole. In the limestone intervals the sand material is dominantly of very fine and fine grade.

### Kyrkheddinge-4

Samples were analyzed from 380 m to the total depth (TD) into 7 fractions using a complete standard set of sieves. Every 6 m from 380 to 642 m and every 4 m from 642 to TD (except for cored intervals) were analyzed. Samples were processed by wet sieving. The cuttings are extremely fine throughout the Lund Sandstone, and contain only minor amounts of aggregated rock material (at the most 5%). Above 495 m the two upper clastic members, 382-448 m and 464-535 m, consist dominantly of coarse-grained sandstones, including occasional conglomeratic beds in the interval 470-495 m. Below this level, medium sand forms the dominant size-class among the sandstones (Fig. 23). This general development of these upper clastic units corresponds well with the character of the sequences recorded in the other Kyrkheddinge borings.

The clastic members throughout the Lund Sandstone are largely composed of poorly consolidated or loose sediments. However, there are also thin layers of hard, well cemented calcareous sandstones/arenaceous limestones. In addition there are minor intercalations of argillaceous limestones, which become more common within the lower clastic members. The sandstone units are therefore very heterogeneous below 757 m. Subrounded and rounded quartz-grains of moderate sphericity dominate the sandstones throughout the Lund Sandstone in KY-4.

### Kyrkheddinge-6 and -7

A total of 43 samples from major sandstone intervals below 757 m in KY-6 and 750 m in KY-7 were analyzed. The samples were dry-sieved into seven fractions.The amount of material in the size interval < 0.125 mm is generally less than 10%, with a maximum of 17% at 750 m in KY-7. The fractions less than 0.125 mm are compiled into one group. The same is done for the fractions larger than 1.0 mm

Table 3. The average grain size from analyzed sand and sandstone units in HA-1, VÄ-3 and VÄ-4.

| HA-1 | | VÄ-3 | | VÄ-4 | |
|---|---|---|---|---|---|
| M | X | M | X | M | X |
| 616 | 0.69 | 507 | 0.60 | 526 | 0.80 |
| 628 | 0.80 | 526 | 0.70 | 548 | 0.66 |
| 646 | 0.85 | 534 | 0.60 | 580 | 0.57 |
| 654 | 0.93 | 542 | 0.50 | 600 | 0.49 |
| 656 | 1.03 | 556 | 0.30 | 616 | 0.56 |
| 674 | 0.73 | 572 | 0.45 | 626 | 0.52 |
| 690 | 0.68 | 598 | 0.32 | 644 | 0.51 |
| 702 | 0.70 | 608 | 0.25 | 660 | 0.45 |
| | | 622 | 0.30 | | |

since there occur only minor amounts of grains larger than 1.0 mm, at the most 0.8%. The sand interval 757-780 m has a fine and medium-grained composition of the sampled sand interval 757-780 in KY-6. The amount of material in the fractions 0.125-0.25 and 0.25-0.5 is about equal. However, coarse-grained beds are found between 760-768 m. The corresponding interval in KY-7, 750-770 m, displays a significantly coarser composition being mainly medium and coarse-grained. The average grain size is 0.21-0.27 mm in KY-6 as compared with 0.38-0.48 mm in KY-7. The deepest lying sand units of the Lund Sandstone are found in the KY-6 and KY-7 borings. These are characterized by well sorted, subrounded dominantly medium and coarse-grained quartz sands with an average grain-size of 0.23-0.32 mm, e.g. between 903 and 996 m in KY-6. In Ky-7 corresponding units (893-1007 m) are somewhat coarser having an average grain size of 0.44-0.50 mm. The grains are generally subrounded or rounded and have a high degree of sphericity

**The Lund borings**

A total of 95 samples coming from various sand/sandstone intervals below approximately 500 metres have been analyzed. The sampled levels in HA-1, VÄ-3 and VÄ-4 are presented in Table 3, together with the mean grain-size. In VÄ-2, SK-1 and SK-2 a more continuous set of analyses render a vertical size frequency plot of the analyzed sections in these borings (Figs. 23, 24).

It must be noted, however that when comparing analyzed sections the Lund Sandstone occurs at significantly greater depths in the Skälsåker and Hansagården area. The Lund Sandstone is coarser in the Lund area compared with the Kyrkheddinge area. The average grain-size is occasionally very coarse graded i.e. 1.03 mm in HA-1 at 643 m (Table 3). There is also in all the investigated borings a trend towards decreasing average grain size with depth. The upper sand units, are due to absence and shortage of lithological samples not analyzed for the grain-size frequency distribution. However, according to the well site lithological logs these units seem to have a similar grain-size character as the upper units of the analyzed sections in corresponding boring.

## Sedimentary structures

Sedimentary structures in the four different main lithofacies are unfortunately badly preserved or difficult to describe due to small diameter cores, core losses in unconsolidated sandstone intervals, and distortion of structures in poorly consolidated beds. Furthermore, cores contribute only to a limited extent to the total amount of lithological samples which are mainly composed of cuttings. In these there are furthermore hardly ever any identifiable structures preserved.

The identifiable structures are mainly found in interbeds of consolidated argillaceous and arenaceous limestones, within major sand/sandstone units. Cores cut in KY-4 in these interbeds (cf. Fig. 26) display a variety of sedimentary structures present in these fine-grained sediment. Most characteristic for the argillaceous beds is the mottled texture with irregular patches and laminae of clay-rich sediment embedded in very fine sand and silt-sized quartz . Occasionally, the clay laminae become more persistent and may form an irregular subparallel banding. It is most likely that the mottled and disturbed bedding is caused by bioturbation and variations of the sediment influx into the

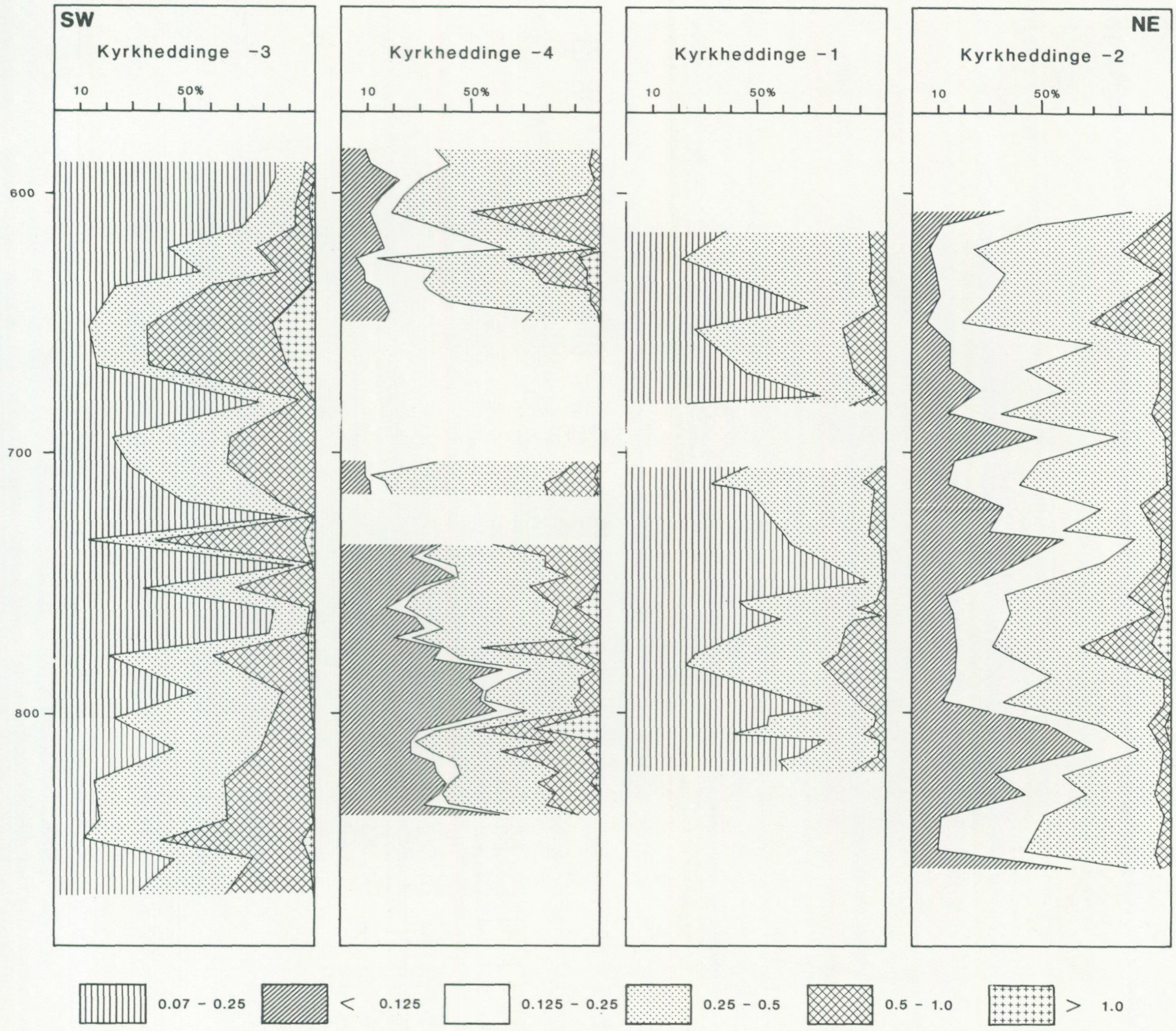


Fig. 22. Grain-size distribution from the SW to the NE in the Kyrkheddinge area, including the KY-3, -4, -1 and -2 borings, below 600 metres (depth in metres below mean sea level).

depositional area. Burrows of variable size are frequently found in cross-sections. The degree of preservation of the original bedding, which seems to be mainly composed of flaser and lenticular bedding, is most likely indirectly related to the rate of sediment influx where intensely bioturbated sediments relate to low rates. Planar lamination is rarely found. A few observations have been made in thin fine- to medium-grained sandstone beds within mainly argillaceous deposits (Fig. 26 ). Disturbed bedding, mainly due to dewatering, is fairly common in thin sand-beds within argillaceous and arenaceous units. Rip-up clast of argillaceous material have also been found in the basal portion of up to one metre thick sands occuring within sequences dominated by limestones.

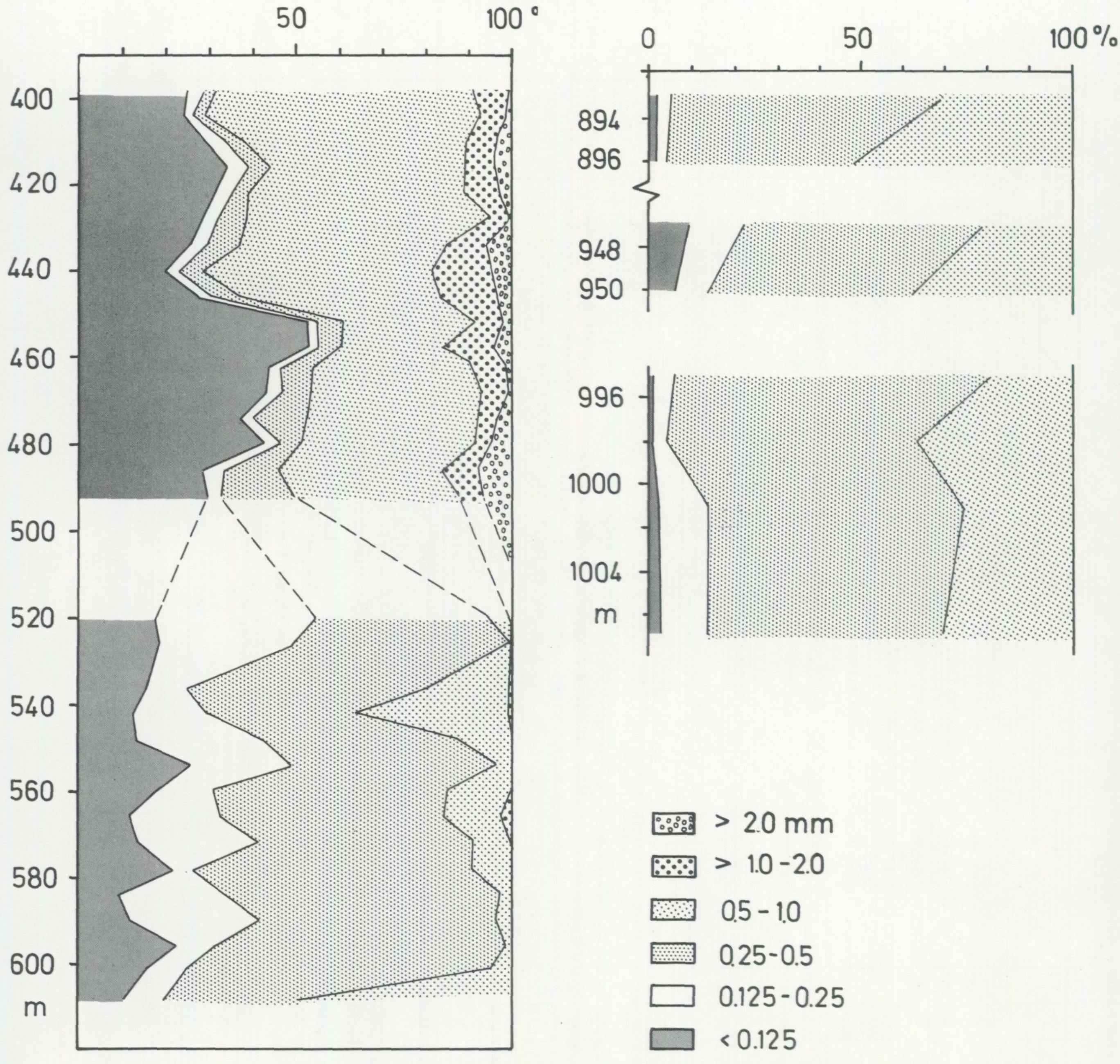


Fig.23. Grain-size distribution graphs on intervals from KY-4 (left) and VÄ-2 (right).

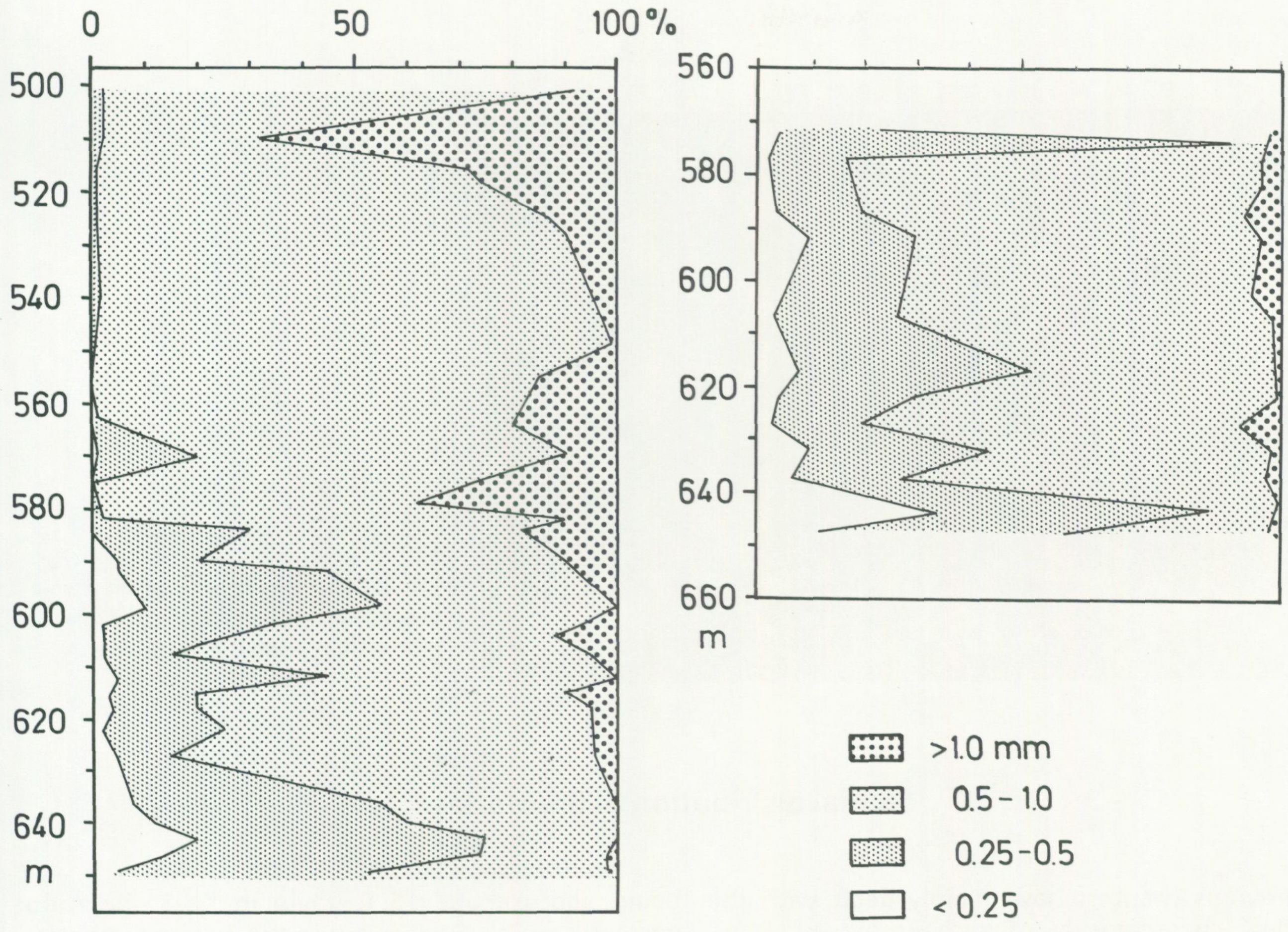


Fig. 24. Grain-size distribution graphs on intervals from SK-1 and -2.

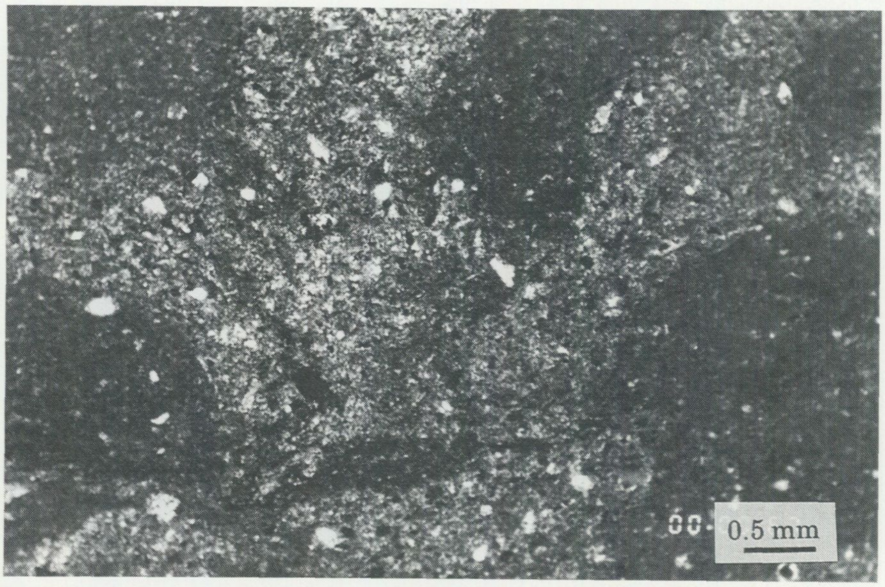


Fig. 25. Microphotograph of an argillaceous limestone sample which displays a mottled, bioturbated microtexture. X-nicols.

## Spatial distribution of lithofacies

The previous chapters have mainly dealt with the individual characteristics of each lithofacies. However, the lithology of the Lund Sandstone also shows lateral and vertical transitions of lithofacial characters, e.g. bed thickness, cementation, grain-size and arenaceous-argillaceous content.

At least in the Lund and Kyrkheddinge area the Lund Sandstone is composed of a series of generally poorly consolidated medium-grained sandstones of variable thickness. In the Kyrkheddinge area the thickest sandstone members are found within the upper 100-200 metres. Singular members in KY-2 reach up to 100 metres in thickness. These upper clastic members appear to wedge out rapidly laterally towards the SW. This is clearly seen in a correlation with corresponding sections in KY-1 and KY-3, where the thicknesses of these units have decreased significantly. In these borings there is also found an increasing number of interbedding argillaceous and arenaceous limestone horizons. This general trend of individual sandstone beds to wedge out towards the SW is a characteristic feature throughout the Lund Sandstone. It is most clearly seen through the sandstone/limestone ratio in the borings along the E-E' section (Fig. 34). In KY-2 there is a clear dominance of sandstone beds, the ratio being approximately 5:1, while in KY-3 the ratio decreases to 3:1. Further out in the Danish Subbasin, e.g. in MO-1, there is a significant decrease of the number of coarse clastic units as well as an overall decrease of the thickness of the Lund Sandstone. However, the individual sandstone beds which are found in the borings situated distally from the Romeleåsen Fault and Flexure Zone, i.e. KY-3, MO-1, SV-1 and BA-1, are generally more distinct in character. This circumstance distinguish them from the more frequently interbedded units of the proximal sandstones in e.g. KY-2, KY-7 and the Lund borings.

The increased heterogeneity of the Lund Sandstone towards the NE and the Romeleåsen Horst is clearly seen in the S4 seismic line, which coincides with the cross-section E-E´ (Fig. 34). There the large number of intraformational markers distinguishes the KY-2 area from the more distal areas which contain fewer and more prominent markers extending far out into the Danish Subbasin.

The lateral heterogenity along the Romeleåsen Fault and Flexure Zone is less well documented, although there seems to be a similar variation of the Lund Sandstone from the SE to the NW as in the SW direction. Coarse clastic deposits are found to grade into more fine-grained deposits to the NW from the Lund area. The Norrevång boring is especially characterized by fine-grained deposits. Vertical and lateral variations of the grain-size occur commonly within the Lund Sandstone. The lateral variation is generally found to involve an overall increase of the grain-size towards the Romeleåsen Horst. Consequently, the sands are mainly composed of fine to medium-grained fractions in KY-1, while being medium and coarse in the KY-2 boring. Similar variations are also found in the direction towards the Norrevång area where dominantly medium-grained sands in the Lund area are represented by fine or very fine-grained beds.

The degree of induration varies considerably in the sandstone units. Cementation is generally of limited lateral extent. It is only occasionally found to comprise a major part of beds. It is usually most difficult to perform a correlation of hard interbeds since their lateral extent is generally less than the minimum distance between borings in the investigated area, i.e. <350 m, which is the distance between KY-2 and KY-7.

The more indurated arenaceous and argillaceous limestones are found both as relatively thin interbeds within the major sand /sandstone members and as more continuous units. The thickness varies from a few metres to 50 m. The core documentation of these beds is comparatively good in the KY-4 boring. The argillaceous content of the Lund Sandstone is found to increase generally towards the basal parts. Consequently the arenaceous limestone beds are found mainly in the upper 100-200 metres of the Lund Sandstone while the more argillaceous analogue occurs predominantly in the lower part. However, occasional argillaceous beds are also found in the upper part interbedding major sandstone units.

## Subsurface structure of the Lund Sandstone

The subsurface structural maps of the Lund Sandstone are based on reflection seismic data from 420 km of seismic lines. Following the designations of markers in previous exploration works the seismic marker defined as the top of the Lund Sandstone is herein called the Tan marker. It is quite easily picked up in the seismograms from the area SW of Lund and by data from the different borings in the area. The development of the Tan marker corresponds to the density contrast between the Lower Maastrichtian argillaceous limestones and the relatively unconsolidated Upper Campanian strata, i.e. the Lund Sandstone. The Tan marker is generally easily mapped since it gives a high amplitude signal in the area. However, the quality of the seismic data is poor to the SE in the Skurup area. This has resulted in a somewhat poorer isochrone mapping of the Tan marker in this area. Between Lund and Landskrona in the NE, the quality of the existing data is better. Thus, it is possible to perform a relatively good subsurface mapping of at least the top of the Lund Sandstone along an approximately 15 km wide zone SW of the Romeleåsen Horst.

The second seismic marker included in this study is the Yellow marker which corresponds to the base of the Lund Sandstone. The marker is of variable quality in the investigated area. Again the data are poor in the SE and best in the vicinity of the town of Lund. The Yellow marker most likely corresponds to the transition between basal sand/sandstone beds of the Lund Sandstone and the underlying more consolidated argillaceous limestones and siltstones of Santonian age.

The deeper lying Blue marker which is the best identifiable marker in the area is only provincially mapped. This marker corresponds to the Cenomanian Sandstone, which is the other major coarse clastic unit in the Upper Cretaceous sequence in SW Scania. It is included in some of the cross-sections shown, just to illustrate the overall thickness variation of the Upper Cretaceous.

Additional minor reflectors are found between the Tan and Yellow markers, especially close to the Romeleåsen Horst. However, their lateral continuity is variable and they are therefore most often difficult to relate to any specific change in lithology. It is likely that they are related to variations in consolidation of the various beds and thus represent local facies changes. These can be related either tolenses of sand, turbidites, beach sands, channel sands and sand bars which interrupt the otherwise relatively uniform sequence of sediments. The variable reflection properties can also represent variations in induration of the different beds. The structural maps presented are all expressed in milliseconds two way travel time (ms, TWT) since there is no accurate velocity data

Fig. 26. Photographs of cores from KY-4. The cored sequence comes mainly from indurated limestone dominated intervals interbedding the major sand/sandstone units in the lower part of the Lund Sandstone .

available for a reliable metric depth conversion over the whole area.

## THE TAN MARKER

The top of the Lund Sandstone (Fig. 27) is developed at approximately 400 ms TWT depth over large parts of the investigated area.The Tan marker is found at shallow depths close to the Romeleåsen Horst. The shallowest identified position is 5 km NW of the city of Lund (Fig. 27). The marker is here found at approximately 150 ms TWT. This shallow occurrence is also evident from some shallow borings in the area, which show that the Lund Sandstone occurs immediately below the Quaternary deposits in a narrow zone, approximately 1-2 km wide immediately SW of the Romeleåsen Fault and Flexure Zone. This is a result of Late Cretaceous inversion movements (Bergström et al. 1987). The zone is disturbed by several faults extending parallel or subparallel to the Romeleåsen Horst, as well as by occasional perpendicular faults. Except for some poorly documented water borings, none of the deeper borings are located in the flexure zone. The interpretation of the structural geology here is therefore somewhat uncertain. However, the seismic data give us a relatively good picture of the extent of the zone. The strongly tilted and faulted strata are displayed in the seismograms as a diffuse zone of disrupted seismic markers and by overall complexity in the seismic signals.

Outside the flexure zone the Tan marker dips gently towards the SW into the Danish Subbasin with 50 ms/1000 m as an average estimate of tilt. The deepest position of the marker in the investigated area is found around 650 ms TWT. As seen in the isochrone map of the Tan marker the general dip towards the SW is by no means of uniform character. Instead there occur several lobe-like anticlinal structures at the top, especially in the Kyrkheddinge area (Fig. 27). Less developed lobes are also present in the vicinity of Lund, Barsebäck, Landskrona and Skurup. The lobes are characteristically narrow in outline and extend generally from a relatively shallow plateau. This is clearly seen in the Kyrkheddinge area but also in the Landskrona area. The lobes are frequently penetrated by faults mainly striking in NE-SW and N-S in addition to the more or less tangential faults in connection to the Romeleåsen Fault and Flexure Zone (Fig. 27). The amplitude is rarely more than 40 ms TWT which corresponds to an estimated metric value of 30-50 metres. The faults are also frequently associated with the larger lobes protruding into the Danish Subbasin (Fig. 27). These faults could result either from syndepositional faulting from postdepositional differential compaction of the underlying beds.

## THE YELLOW MARKER

The Yellow marker corresponds to the base of the Lund Sandstone. It is generally less well developed than the Tan marker, especially in the distal parts of the mapped area. This restricted the area which could be mapped in comparison with the area mapped with the Tan marker.

A slight downwarping of the basal beds as shown in the isochrones of the Yellow marker coincides with the lobes defined by the isochrones of the Tan marker. This is especially seen in the Kyrkheddinge area (Fig. 28). The average time equivalent depth of the Yellow marker lies around 800 ms TWT, the more shallow parts at approximately 600 ms and the deeper parts at 950 ms. Again the deepest observations come from the more central parts of the Danish Subbasin (Fig. 28).

The marker is relatively undisturbed by faulting. Only a few of the major faults penetrates the Tan marker and reach down into the Yellow marker. Closer to the Romeleåsen Fault and Flexure Zone the structure of the marker is more complex and disturbed and therefore difficult to trace properly.

Time isopach maps produced for the Lund Sandstone (Fig. 29) show a significantly increased thickness of the separate beds in the Kyrkheddinge and Lund areas. A maximum thickness of 600 ms TWT is found in the central parts of the Kyrkheddinge area (Fig. 29). The Lund Sandstone is considerably thinner with an average thickness of approximately 300 ms (Fig. 29) at corresponding distances, i.e. 10-15 km, from the Romeleåsen Fault and Flexure Zone in the NW, approximately 15 km from the city of Lund. Thicker deposits are also found at the far northwestern part of the investigated area, just outside the town of Landskrona (Fig. 29).

The cross-sections A-E (Figs. 5, 30-34) display the lateral thickness variations along the Romeleåsen Fault and Flexure Zone and the significant increase in thickness of the Lund Sandstone towards the horst. Close to the horst, the thick accumulation of Campanian clastics has also resulted in a significant downwarping of deeper units in the Cretaceous, e.g. the Cenomanian Sandstone. This is clearly evident from the structural development of the Blue marker, which defines approximately the Lower/Upper Cretaceous transition.

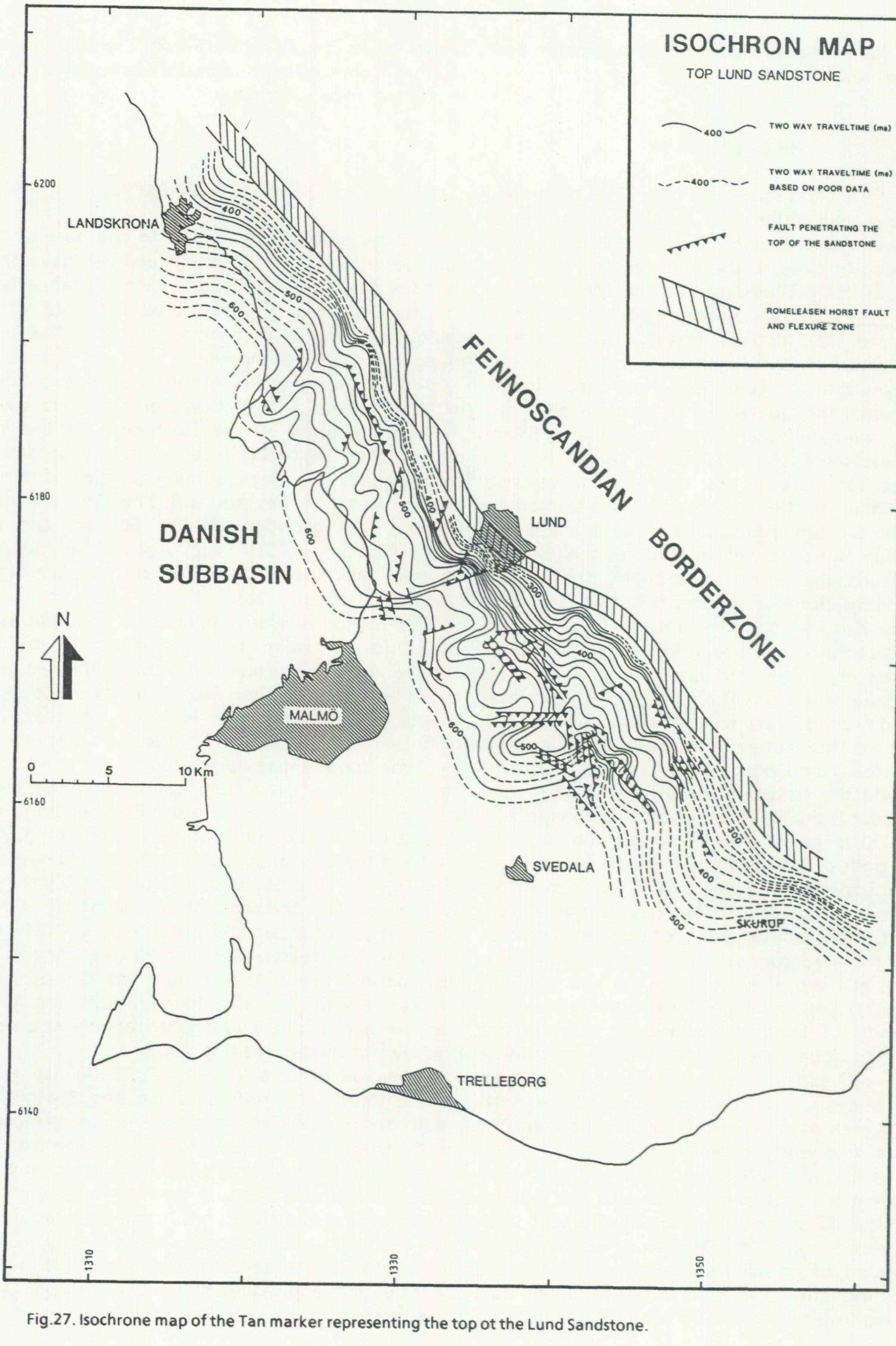


Fig.27. Isochrone map of the Tan marker representing the top ot the Lund Sandstone.

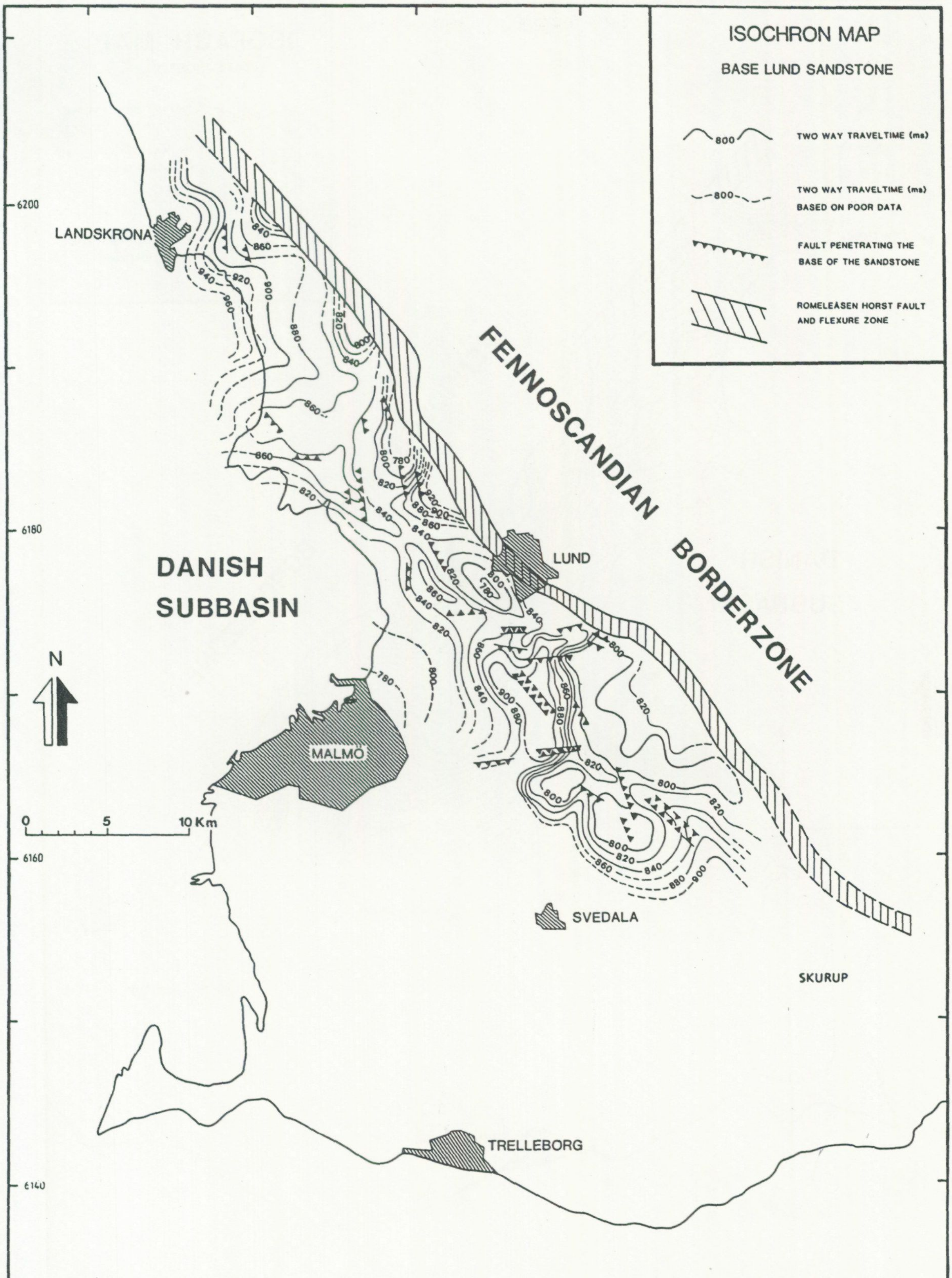


Fig. 28. Isochrone map of the Yellow marker repesenting the base of the Lund Sandstone.

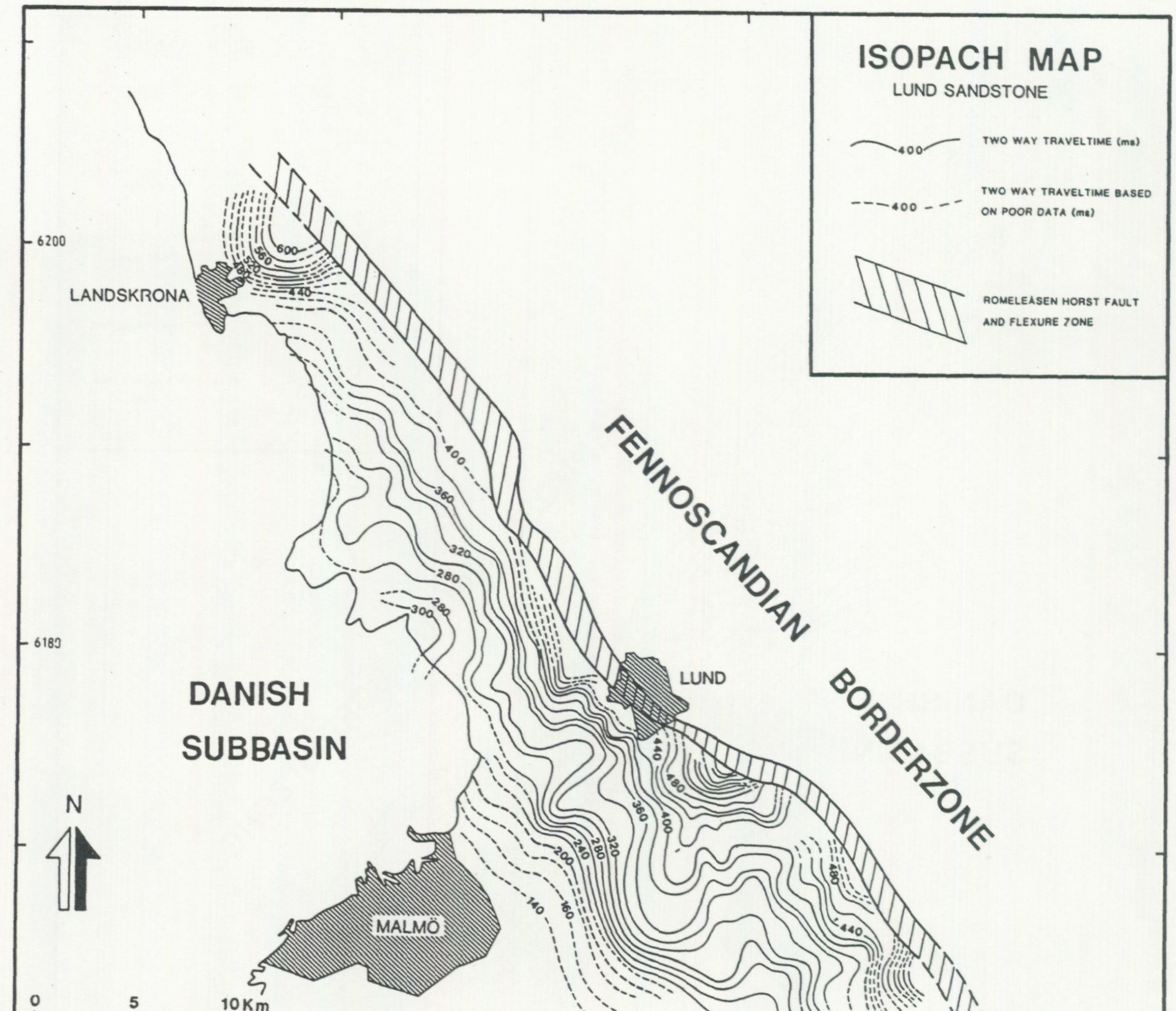


Fig. 29. Isopach map of the Lund Sandstone.

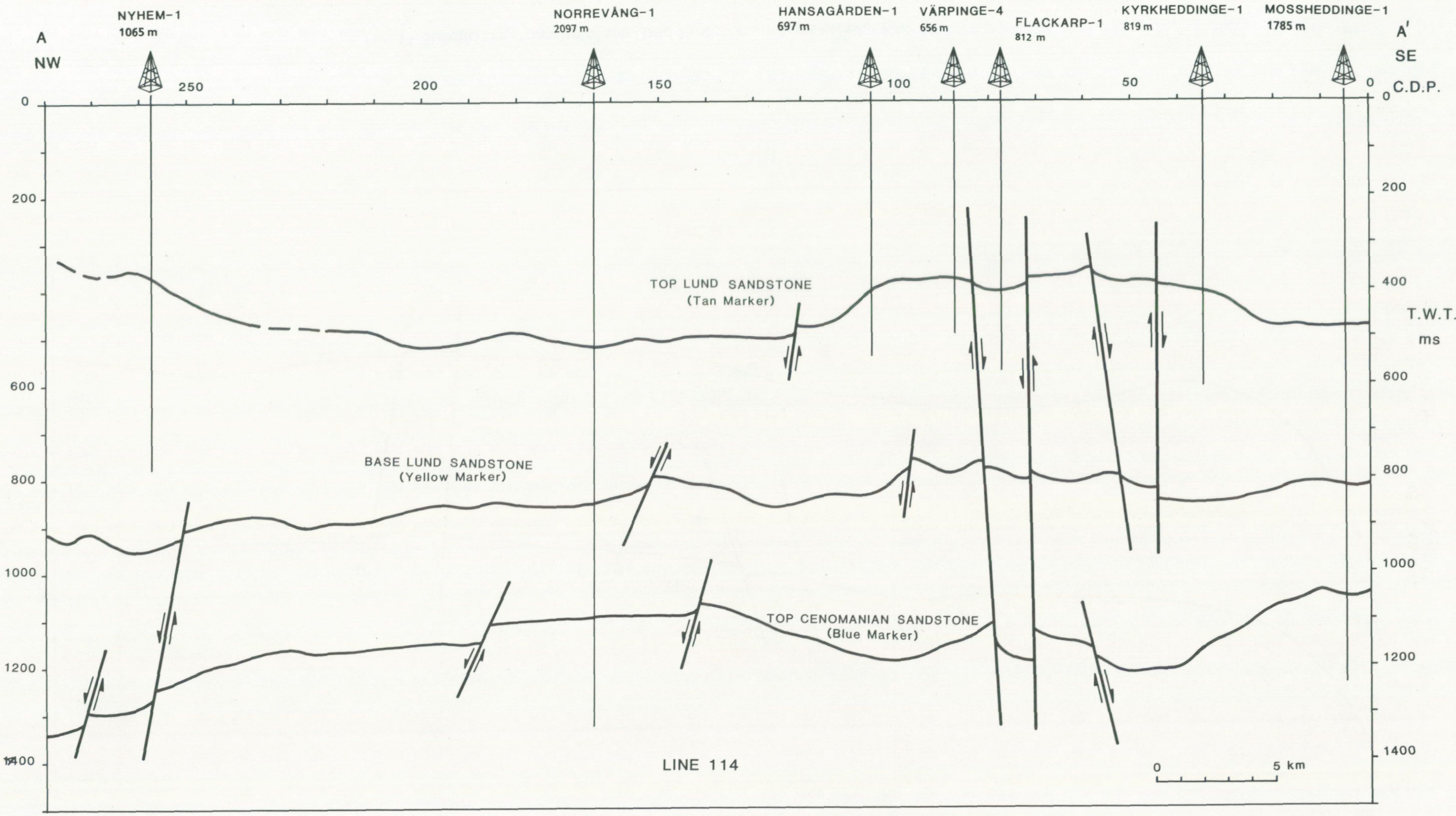


Fig 30. Subsurface structure of the Lund Sandstone in cross-section A-A'

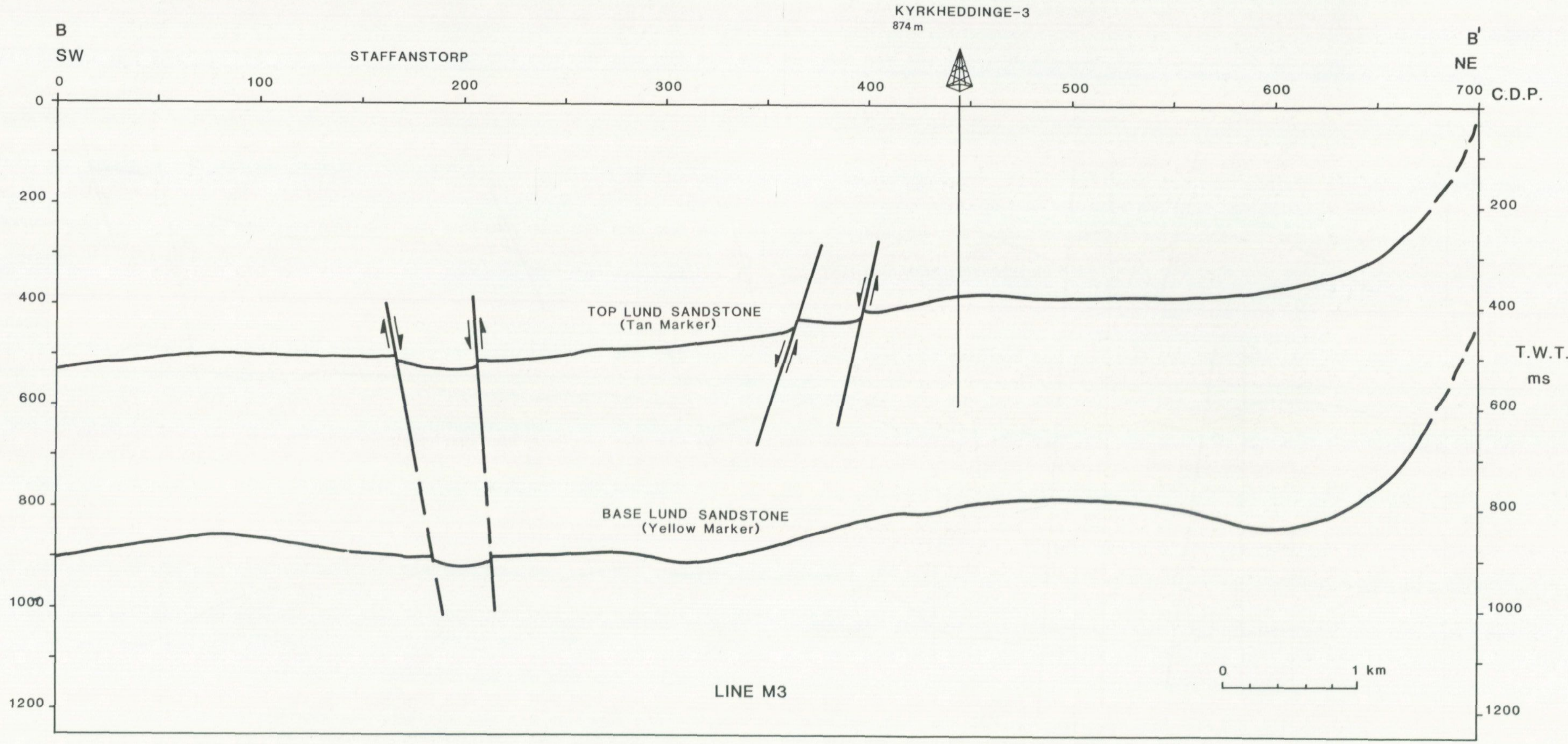


Fig. 31. Subsurface structure of the Lund Sandstone in cross-section B-B'

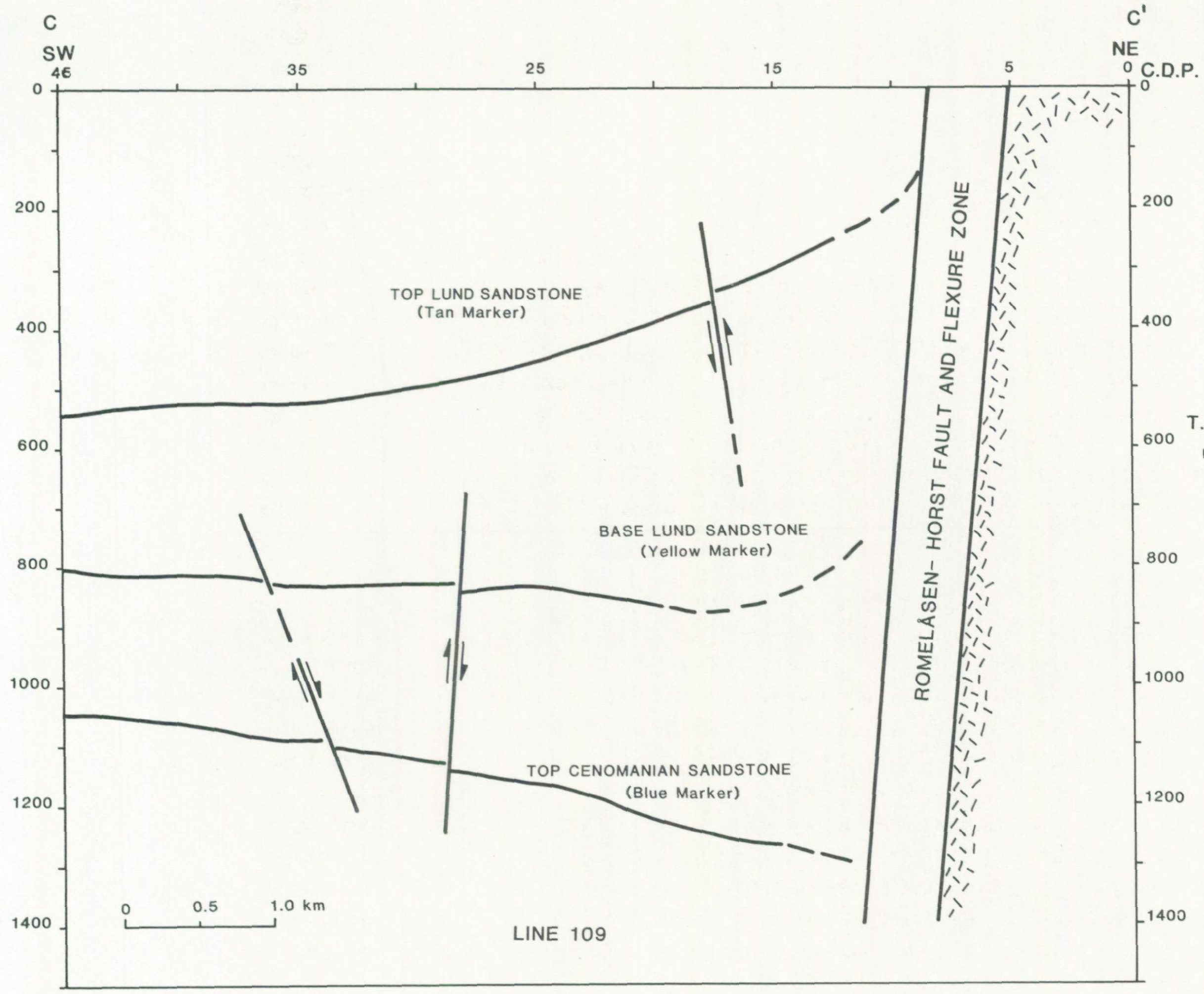


Fig. 32. Subsurface structure of the Lund Sandstone in cross-section C-C'

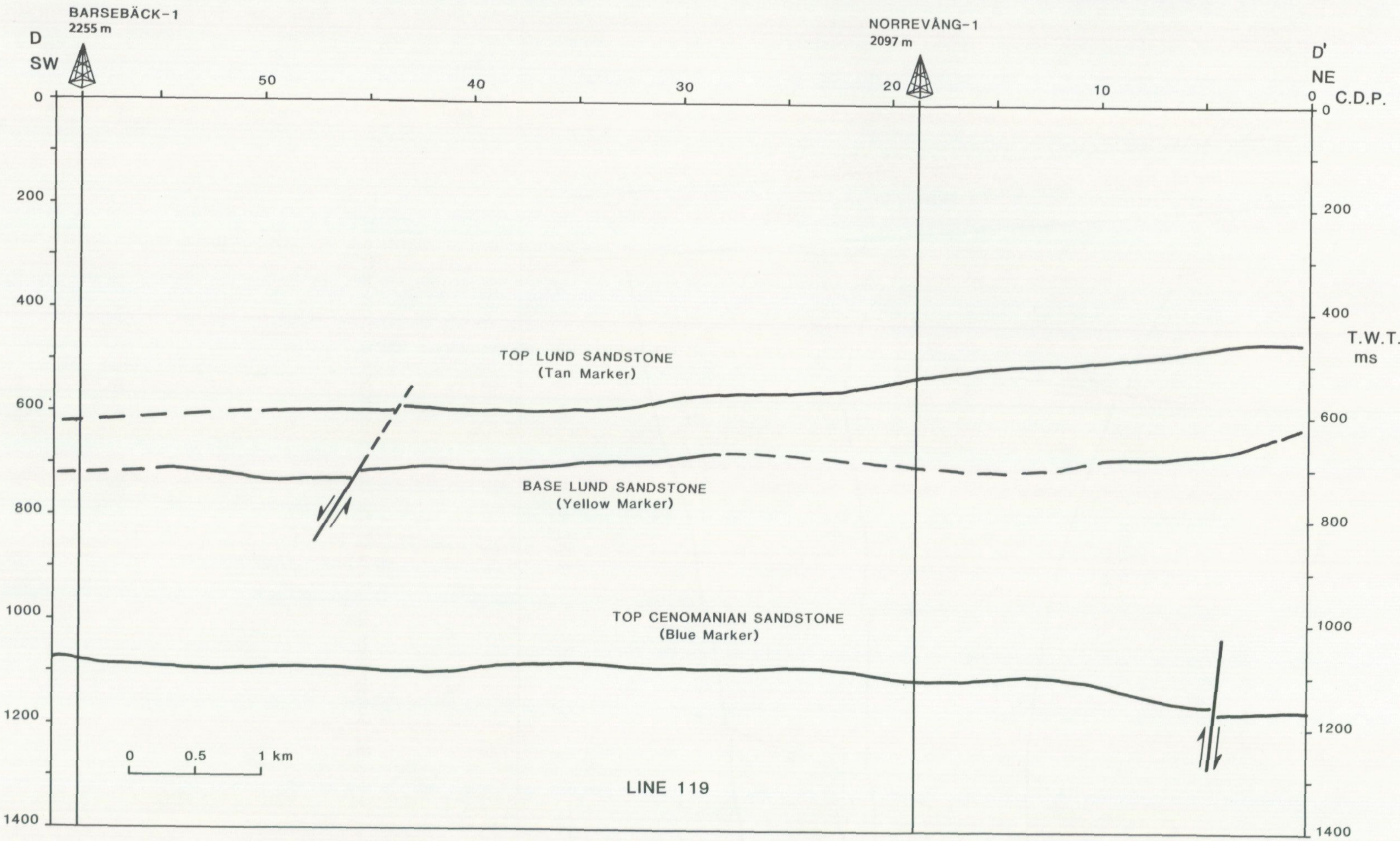


Fig. 33. Subsurface structure of the Lund Sandstone in cross-section D-D'

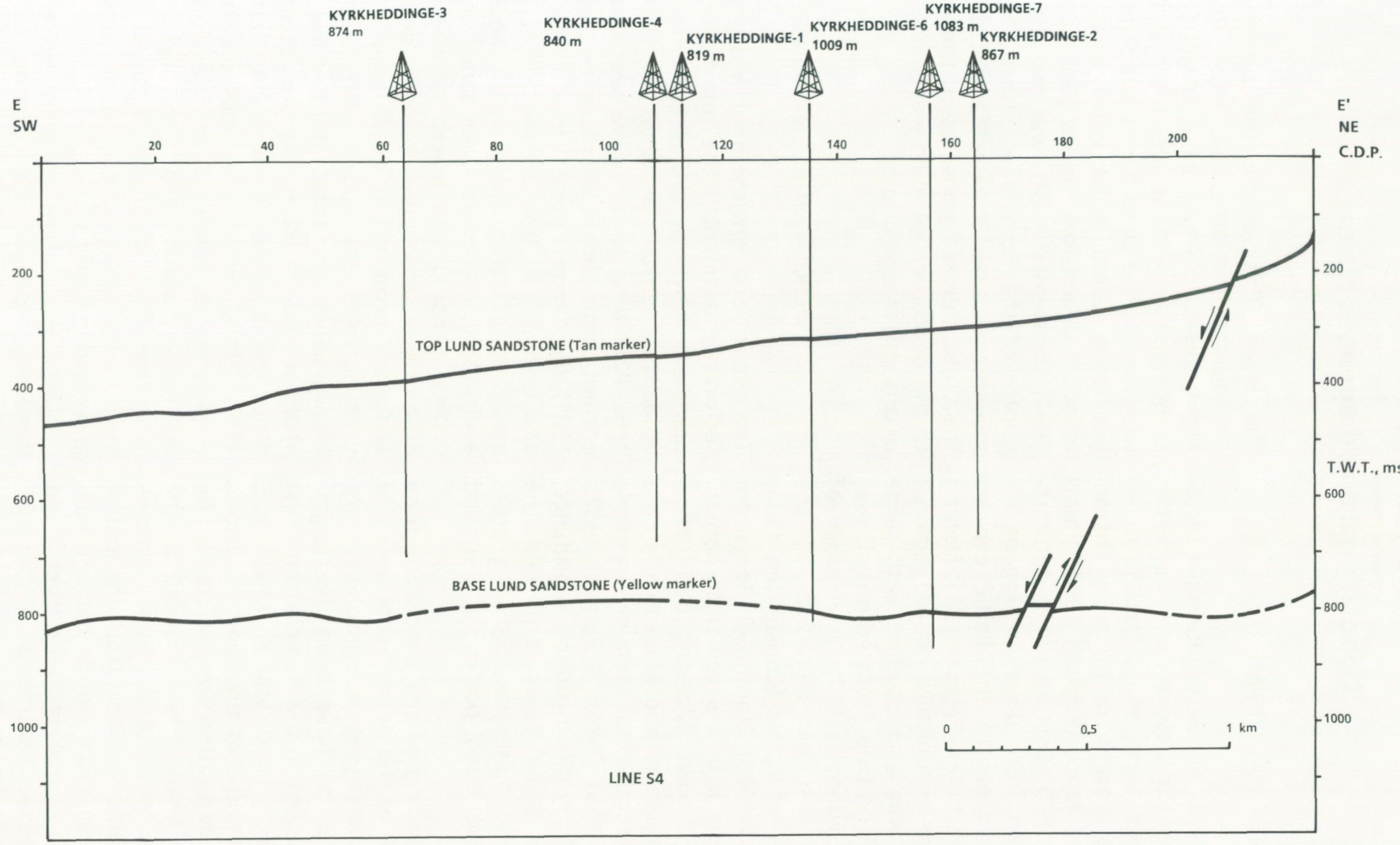


Fig. 34. Subsurface structure of the Lund Sandstone in cross-section E-E'

## Depositional and diagenetic history

### DEPOSITIONAL REGIME

The Lund Sandstone was deposited during a tectonically active interval of the Mesozoic Era. During this interval the Tornquist zone and adjacent depositional areas to the west were primarily characterized by active subsidence (Pegrum 1984; Baartman & Christensen 1984). Compressional deformation coupled with significant downwarping of SW Scania and adjacent areas in the Baltic evolved during Late Cretaceous times (Pegrum 1984; Norling & Bergström 1987). The tectonically induced regional depositional regime was also coupled with large scale transgression of the Late Cretaceous shelf seas in Europe (Tyson & Funnell 1987). A number of transgressive pulses can be identified in the sedimentary sequence of Scania (Christensen 1984; Gabrielson & Holland 1986; Norling & Bergström 1987). Major pulses occur in the Lower Santonian, Middle Campanian and Lower Maastrichtian (Christensen 1984). The Campanian and Maastrichtian are also considered to reflect the maximum extent of the European Cretaceous seas (Tyson & Funnell 1987). The combination of syndepositional subsidence, inversion movements (uplift/downwarp) and the regional transgressional pulses resulted in a great complexity of the depositional pattern of the Lund Sandstone.

The structural mapping of the Lund Sandstone reveals the subsidence of the depositional area and the downwarping of underlying stratigraphical units. The subsidence appears to have been most significant in the area adjacent to the Romeleåsen Horst and especially between Lund and Kyrkheddinge, where the thickest deposits of the Lund Sandstone are found. The clastic deposition was initiated in the Late Santonian. Most likely it was induced by the Santonian regressional phase and inversion movements along the Romeleåsen Horst. Until the end of the Campanian a landmass to the north constituted a continuous source-area for the detrital clastics found in the Lund Sandstone. Fragments of Jurassic, Silurian and Cambrian sediments and crystalline rock fragments are commonly found in the sandstone beds of the Lund Sandstone. This indicates a source area with a bedrock surface similar in composition to the area immediately NE of the Romeleåsen Fault and Flexure Zone today. The rate of deposition was more or less identical with the rate of subsidence of the basin. This led to the preservation of the depositional pattern. The major inversion movements seem to have taken place during the late Campanian since it includes the major coarse clastic members of the Lund Sandstone. The mid-Campanian transgressional pulse, which is recognized in the adjacent depositional areas (Gabrielson & Holland 1984; Christensen 1984), was masked locally by the uplift of the Romeleåsen Horst. Most likely the movements ceased in early Maastrichtian times when the Cretaceous sea transgressed the area, which led to the deposition of mainly argillaceous limestones of offshore marine origin.

### DEPOSITIONAL ENVIRONMENT

The depositional environment was governed by the tectonic movements, the main shore-line type, dominant physical processes, climate, and the amount of detrital clastics deriving from the source-area. According to a review over characteristics of ancient clastic dominated shoreline deposits (Heward 1981), the deposits possess four different geometries and origins, i.e. transgressive sheet sands (deltaic association), transgressive sheet sands (non-deltaic association), regressive sheet sands and linear sand bodies. A rising source-area normally generates a high rate of sedimentation in the depositional area and thus favours the development of regressive sheet sands in association with prograding deltas. Transgressive sand-sheets formed by reworking of abandoned delta lobes may also occur locally in an otherwise progressive delta association (Heward 1981). These two major types of associations are considered to dominate the development of the sedimentary sequence of the Lund Sandstone. The main characteristics of the identified lithofacies and their interpreted depositional environment is presented in figure 35.

Large volumes of sediment were deposited in three major depositional centrum, i.e. in the Kyrkheddinge, Lund and Landskrona areas. In addition, there are indications of another centra in the Skurup area to the southeast. Probably other depositional centra occur towards the NW along the Romeleåsen Fault and Flexure Zone as indicated by the more than 100 m of Campanian sandstones described by Larsen et. al. (1968) from the Öresund area. Especially in the

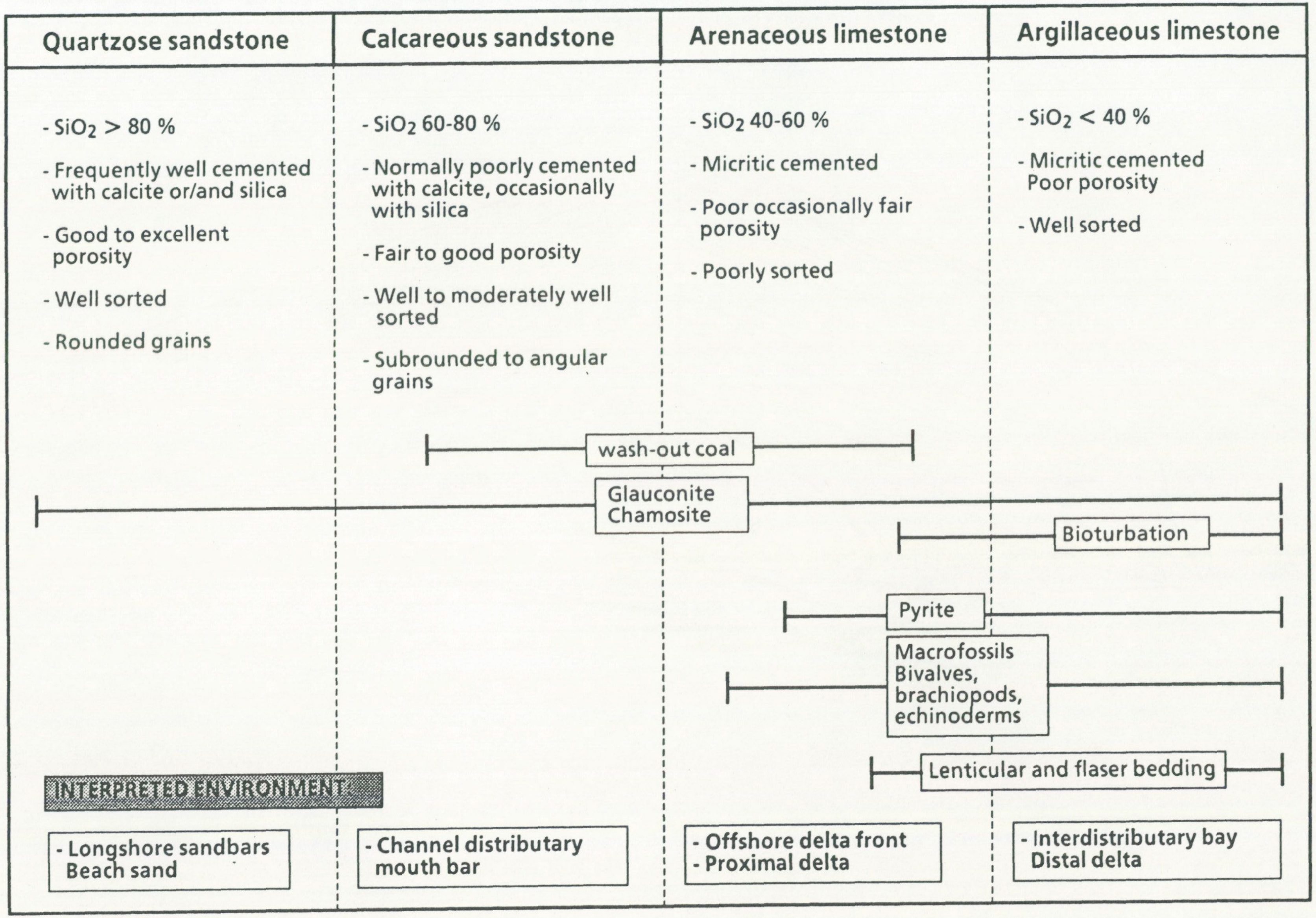


Fig. 35. Summary of the diffe-ent characteristics of the four main lithofacies in the Lund Sandstone together with an interpreted main depositional environment.

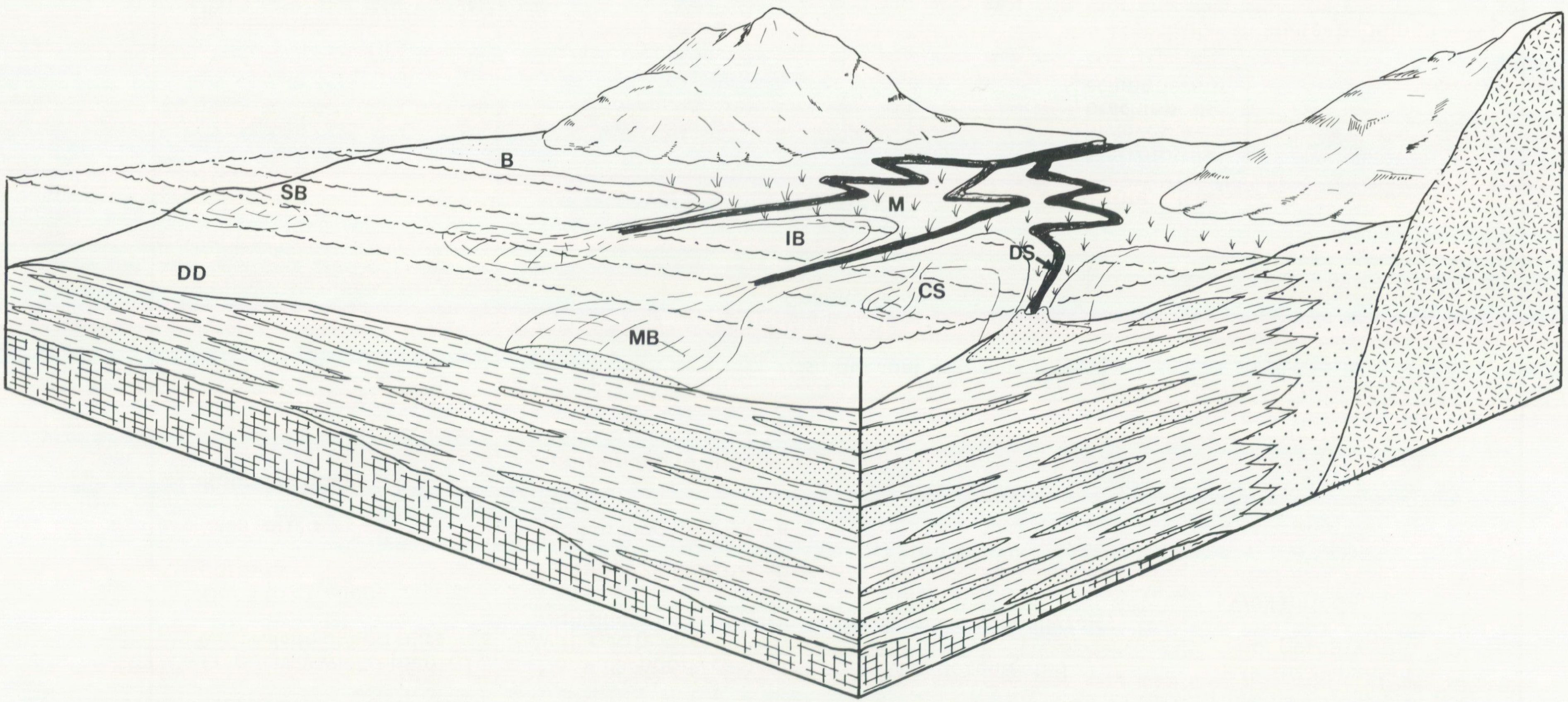


Fig. 36. Schematic reconstruction of the depositional environment of the Lund Sandstone during a phase of the Late Campanian.
MB: Mouth bar IB: interdistributary bay DD: Distal delta B: Beach CS: Crevasse splay DC: Distributary channel M: Marsh SB: Sand bar.

Kyrkheddinge area the structural development of the Lund Sandstone shows a series of lobes of thicker deposits extending far into the Danish Subbasin. These are interpreted to represent prograding delta-fronts and rapid accumulation of clastic material transported by river systems from the NE.

A number of subenvironments are identified in the borehole sections penetrating these lobes. In addition to the four main lithofacies there occur also environmental indicators in the spatial development of the facies. The sandstone members were generally deposited in a regressive sand sheet association of mouth-bar and distributary channel origin. These sands generally involve a coarsening upward association of argillaceous limestones deposited in an offshore distal delta environment. These are succeeded by arenaceous limestones of proximal delta origin. These limestones are topped by fine to medium-grained sandstones. The sandstone member in itself may be fining upwards reflecting an abandonment phase and infilling of the distributary channel with finer sediments in a low energy regime. The thicknesses of the coarsening upward cycles are found to vary between 10 to 100 metres in the Kyrkheddinge area. Reworking of a deposited cycle by currents and waves during subsidence of an abandoned distributary channel is most likely the cause of the occurrence of incomplete units less than 10 m in thickness

The quartzose medium to coarse-grained and occasionally conglomeratic sandstones are generally very well sorted with rounded grains and a low amount of accessory minerals other than glauconite, which is found in significant amounts. The basal part of the sandstone sequences are frequently found to be erosive and contain centimetre-large mud-clast from underlying beds, i.e. as seen in a core-sequence from KY-4. The beds are most commonly between 1 and 10 metres thick from what is observed in Kyrkheddinge area. These distinguishing characters indicate a different origin of these deposits. Reworking and local destruction of prograding deltas occur commonly. This leads to the development of well sorted sand bodies associated with the active delta as a result of wave and current reworking of distributaries. The developed long-shore sandbars are generally underlain by arenaceous and argillaceous limestones of inter-distributary bay or lagoons and lateral offshore delta front origin. They are commonly overlaid by mouth-bar sands and interdistributary bay deposits.The interdistributary bay sediments are normally deposited in a open marine elongate body of water surrounded by marshes and distributary channels. The sediments consist of dominantly argillaceous, silty and variably calcareous deposits. The more fine-grained beds are generally intensively bioturbated. Transected burrow traces are commonly found in core material from KY-1 and KY-4. Increased supply of sediment, mainly silt and very fine-grained sand, into the area led to the development of flaser and lenticular bedding. The structures are relatively undisturbed by bioturbation. In addition this indicates a slightly higher rate of sedimentation for these units. In the Kyrkheddinge area the interdistributary bay deposits also occasionally include very organic-rich fine-grained, up to 0.5 m thick, beds likely formed in a marsh environment. Root bottoms have not been recognized in the investigated sections. It is therefore difficult to interpret whether the beds are formed in situ or represent outwash organic deposits. Furthermore, the bay deposits are commonly interbedded by bay fills (crevasse splays) composed of less than 1 m thick coarse-grained clastic deposits having an erosional base and a fining upward character. The deposits formed by a break in a distributary channel, for instance during a flood stage, where channel-transported clastics diverted into the interdistributary bay. The deposits reflect an initial high flow regime during the break-through and the gradually decreasing and waning flow as the crevasse splay became inactive. Dewatering structures are commonly found in the crevasse splay deposits indicating a rapid deposition of the coarse clastics. Subsequent compaction of the sediments during burial caused deformation and release of overpressured pore-water. Deposits of this kind are commonly found in the argillaceous deposits in the Kyrkheddinge area.

## DEPOSITIONAL MODEL

In the Kyrkheddinge and Lund areas the Lund Sandstone is dominated by deposits of deltaic origin. The basal 100-200 metres of the Lund Sandstone is more frequently alternating between distal delta argillaceous limestones and fine-grained matrix-rich sands of lateral mouth-bar origin. This heterogeneity becomes more pronounced to the SW in more central parts of the Danish Subbasin. The deepest laying sands of Santonian age found in KY-6 and KY-7 are, however, interpreted as of more proximal character due to their medium to coarse-grained, well sorted composition and thickness. Probably they are developed only locally, since the seismic markers associated with these strata disappear outside the Kyrkheddinge area. The upper part of the Lund Sandstone is characterized by proximal delta deposits with cyclic deposits composed of argillaceous and arenaceous limestones, of delta front and interdistributary bay origin, with interbedded occasional bay fill sediments overlaid by variably calcareous sandstones of mouth-bar and distributary channel origin and longshore bars composed of quartzose sandstones. Figures 35 and 36 represent an attempt to reconstruct the depositional environment in the Kyrkheddinge area during the Late Campanian, when a number of distributaries in a wave-dominated delta supplied large volumes of clastics into the marginal parts of the Danish Subbasin.

## POSTDEPOSITONAL PROCESSES

The diagenesis of a clastic deposit such as the Lund Sandstone is very complex in nature. The postdepositional processes can primarily be related to inherited properties of the sediment and factors of dynamics, temperature and porewater chemistry (Wolf & Chilingarian 1976).

The Lund Sandstone is only buried to moderate depths defined as the eugenetic regime by Schmidt and McDonald (1979) where compaction and precipitation of early cements dominate. At depths between 400 and 1100 metres the subsurface temperature in the area ranges from 15 to 30° C. It is possible that higher temperatures prevailed during intervals of the postdepositional history of the Lund Sandstone. The temperature is not likely to have ranged above 50° C, since the sediment has been subjected to only minor alteration and dissolution.

Therefore the irregular presence of silica and carbonate cements is instead related to heterogeneous compaction, chemistry of trapped porewater-fluids and variation of the redox-potential. Silica cemented sandstones are most commonly found in connection with argillaceous beds, most oftenly as single thin interbeds. Dissolution of quartz-grains has not been found to such an extent as to explain the occurrence of these silica cemented units. The contacts between grains are consequently characterized by edge to edge or long interface-type. Most of the silica is therefore interpreted as deriving from an external source. The presence of early diagenetic silica cement in sandstones may be the result of percolating meteoric water from deeper laying sediments and supersaturation with respect to silica (Bjørlykke 1983). Another possible origin may be the release of supersaturated waters from compaction of adjacent argillaceous beds (Füchtbauer 1979; Boles & Franks 1979). A minor amount of the precipitated silica may originate from kaolinitization of feldspars which results in the release of silica in addition to the formation of authigenic kaolinite. However, the few findings of authigenic kaolinite indicate that only a minor amount of silica can have derived from kaolinitization of feldspars. Instead it is most likely that the bulk of the silica emanates from compaction of argillaceous beds, of interdistributary bay or distal delta origin. This especially leads to the cementation of thin porous interbeds of crevasse-splay type. The major sand-units of mouth-bar origin are relatively free from silica cement which also favours the theory of silica enriched solutions coming from the argillaceous beds and precipitation in isolated porewater systems as in a crevasse splay deposit of limited lateral and vertical range.

Calcite cement is commonly found throughout the Lund Sandstone. Most likely it postdates the silica cement since synformational slightly alkaline pore waters would prevent precipitation of silica. The microcrystalline silca cement have occassionally been affected by solution due to alkaline conditions (Fig.17). The calcium carbonate derives from dissolution of fossil shells in calcareous sandstones. The subsequent precipitation was initiated when no more carbonate could be kept in solution at prevailing temperature and pH. Variations of saturation has occasionally led to patchy cementation of the rock.

Pyrite occurs as nodules in matrix-rich fine-grained sandstones and in the limestones as cement replacing calcite cement or as centimetre large nodules. The pyrite was therefore presumably formed after the calcite cement as a result of reducing conditions in the pore waters.

Summarizing this discussion the Lund Sandstone has undergone an initial phase of compaction which led to heterogeneous overburden pressure according to local thickness variations. Early release of supersaturated pore waters from relatively more compacted argillaceous beds resulted in an early cementation of silica in isolated thin sandy layers. Subsequently calcium carbonate cements precipitated as a result of supersaturation and increasing burial temperature. The last phase involved precipitation of pyrite. The volume of the cemented sandstones did not change substantially during burial. However, the cementation resulted in a reduction of the porosities, especially in the silica cemented layers.

## Acknowledgements

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# Appendix

## WELL DATA

### Kyrkheddinge-1

**Location:** 150 m west of the old railway station in Kyrkheddinge
**Coordinates:** 55°39'09''N 13°16'00''E X 617198 Y 133985
**Total depth:** 819.48 m b sl
**Elevation:** 23.37 m a sl (measured from the Kelly Bushing, KB)
**Lund Sandstone:** 402-Total Depth (TD)
**Samples:** 180-TD : Every three metres except for cored sections.
**Cored sections:** 399.81-407.34 m, 459.73-461.23 m, 546.68-612.10 m, 661.40-819.48 m
**Geophysical logs:** 0-397.63 m: Gamma Ray, Sonic 397.63-812.48 m Gamma Ray, Single Point Resistivity, Sonic, Gamma-Gamma, Lateral Resistivity, Normal resistivity, Caliper Vertical seismic profile, Temperature log.

### Kyrkheddinge-2

**Location:** 100 m east of Bjällerup church, 1100 m north of KY-1
**Coordinates:** 55°39'34''N 13°15'57''E X 617306 Y 134000
**Total depth:** 866.68 m b sl
**Elevation:** 19.92 m a sl (KB)
**Lund Sandstone:** 322.08-TD
**Samples:** 0-188.08 m: No recovery 188.08-526.08 m: Every six metres 526.08-TD: Every three metres
**Cored sections:** 748.29-752.79 m, 773.08-777.04 m, 779.66-780.24 m, 844.28-846.00 m
**Geophysical logs:** 0-526.08 m:Gamma Ray, Sonic, Single Point Resistivity. 526.08-TD :Gamma Ray, Sonic, Single Point Resistivity, Selfpotential, Gamma-Gamma, Lateral Resistivity, Normal Resistivity, Caliper

### Kyrkheddinge-3

**Location:** 1050 m WSW of Kyrkheddinge church, 950 m SSW of KY-1.
**Coordinates:** 55°38'34''N 13°15'30''E X 617110 Y 133947
**Total depth:** 872.20 m b sl
**Elevation:** 22.61 m a sl (KB)
**Lund Sandstone:** 471.4-TD
**Samples:** 0-175.39 m: No recovery 175.39-538.39 m: Every six metres 538.39-TD m: Every three metres
**Cored sections:** 653.10-657.6 m, 676.06-678.9 m, 689.10-693.6 m, 699.75-704.06 m, 708.30-712.80 m, 734.50-735.76 m, 786.16-790.66 m, 803.50-808.00 m, 833.10-836.82 m
**Geophysical logs:** 0-538.39 m: Gamma-Ray, Sonic, Single Point Resistivity. 538.39-871.39 m: Gamma-Ray, Single Point Resistivity, Sonic, Gamma-Gamma, Lateral Resistivity, Normal Resistivity, Caliper, Selfpotential.

### Kyrkheddinge-4

**Location:** 350 m W of the old railway station in Kyrkheddinge, 1050 m NW of Kyrkheddinge church.
**Coordinates:** 55°38'96''N 13°15'58''E X 617200 Y 133950
**Total depth:** 840.18 m b sl
**Elevation:** 20.12 m a sl (KB)
**Lund Sandstone:** 381.88-TD
**Samples:** 0-34.88 m: No recovery 34.88-379.88 m: Every five metres 379.88.733.88 m: Every four metres 733.88-TD: Every two metres
**Cored sections:** 607.38-618.78 m, 652.28-659.58 m, 660.38-702.88 m, 724.68-733.88 m
**Geophysical logs:** 0-494.88 m: Gamma-Ray, Sonic, Selfpotential, Caliper. 180.88-494.88 m:Resistivity, Gamma-Gamma 494.88-839.88 m: Dual Induction Log, Gamma-Ray.

### Kyrkheddinge-5

**Location:** 450 m SW of Kyrkheddinge old railway station, 250 m S of the railway.
**Coordinates:** 55°38'89''N 13°15'57''E X 617172 Y 133959
**Total depth:** 734.43 m b sl
**Elevation:** 19.47 m a sl (KB)
**Lund Sandstone:** 415.53-TD
**Samples:** 0-88.53 m: No recovery 88.53-180.53 m: Every six metres 180.53-734.43: Every three metres
**Cored sections:** 730.03-730.83 m
**Geophysical logs:** 43.53-575.53 m: Gamma Ray, Selfpotential, Induction, Focused Resistivity, Caliper 575.53-733.53 m: Gamma Ray, Selfpotential, Induction, Focused Resistivity, Caliper.

### Kyrkheddinge-6

**Location:** 500 m S of Bjällerup church, beside the road between Bjällerup and Kyrkheddinge.
**Coordinates:** 55°39'38''N 13°15'81''E X 617255 Y 133982
**Total depth:** 1009.05 m b sl
**Elevation:** 19.87 m a sl (KB)
**Lund Sandstone:** 352.13-TD
**Samples:** 0-82.13 m: No recovery 82.13-180.13 m: Every six metres 180.13-1009.05: Every three metres
**Cored sections:** 727.05-738.15 m
**Geophysical logs:** 43.13-504.13 m: Gamma Ray, Selfpotential,

Caliper. 550.13-1008.13 m: Gamma Ray, Selfpotential, Caliper. 550.13-921.13 m: Sonic. 550.13-859.13 m: Density. 550.13-932.13 m: Focused Resistivity.

### Kyrkheddinge-7

**Location:** 250 m SE of Bjällerup church.
**Coordinates:** 55°39'54"N 13°15'95"E X 617292 Y 133988
**Total depth:** 1083.4 m b sl
**Elevation:** 19.41 m a sl (KB)
**Lund Sandstone:** 330.59-895.59 m
**Samples:** 0-80.59 m: No recovery. 80.59-180.59 m: Every six metres. 180.59-1083.4 m: Every three metres.
**Cored sections:**----
**Geophysical logs:** 46.59-604.59 m: Gamma Ray, Selfpotential, Caliper, Induction. 574.59-1082.59 m: Gamma Ray, Selfpotential, Caliper, Induction. 574.59-1073.59 m: Sonic, Density, Neutron.

### Flackarp-1

**Location:** 350 m SE of the railway, 250 m WSW of the Höje stream.
**Coordinates:** 55°41'08"N 13°10'17"E X 617624 Y 133406
**Total depth:** 801.9 m b sl
**Elevation:** 21.1 m a sl (KB)
**Lund Sandstone:** 518.9-TD
**Samples:** 0-518.9 m: Every three metres 518.9-801.9 m: Every two metres
**Cored sections:** 725.36-734.5 m
**Geophysical logs:** 550.9-798.9 m: Gamma Ray, Selfpotential,Caliper, Resistivity.

### Värpinge-1

**Location:** 200 m SSE of the cross-road to Önnerup in Värpinge.
**Coordinates:** 55°42'14"N 13°09'04"E X 617794 Y, 133296
**Total depth:** 749.9 m b sl
**Elevation:** 13.1 m a sl (KB)
**Lund Sandstone:** 409.9-TD
**Samples:** 0-409.9 m: Every three metres 409.9-749.9 m: Every two metres
**Cored sections:**----
**Geophysical logs:** 551.9-746.9 m: Gamma Ray, Selfpotential, Caliper, Resistivity.

### Värpinge-2

**Location:** 350 m N of the centrum of Värpinge village, 600 m N of VÅ-1.
**Coordinates:** 55°42'46"N 13°09'00"E X 617842 Y 133292
**Total depth:** 635.46 m b sl
**Elevation:** 20.54 m a sl (KB)
**Lund Sandstone:** 446.46-TD
**Samples:** 0-449.45 m: Every three metres 449.45-TD: Every two metres
**Cored sections:** ----
**Geophysical logs:** 0-429.46 m: Gamma Ray (inside casing) 447.46-TD: Caliper, Acoustic, Gamma Ray

### Värpinge-3

**Location:** 150 m ENE of the cross-road to Önnerup in the village of Värpinge
**Coordinates:** 55°42'30"N 13°09'16"E X 617818 Y 133311
**Total depth:** 611.46 m b sl
**Elevation:** 18.54 m a sl (KB)
**Lund Sandstone:** 396.46-TD
**Samples:** 0-451.46 m: Every three metres 451.46-TD: Every meter
**Cored sections:** ----
**Geophysical logs:** 0-484.46 m: Gamma Ray 484.46-610.46 m: Gamma Ray, Acoustic, Caliper, Dual Guard-Forxo

### Värpinge-4

**Location:** Immediately S of the "Höjeåvägen", 450 m SE of the village of Värpinge
**Coordinates:** 55°42'04"N 13°09'33"E X617781 Y 133216
**Total depth:** 655.65 m b sl
**Elevation:** 16.35 m a sl (KB)
**Lund Sandstone:** 406.65-TD
**Samples:** 0-58.65 m: No recovery 58.65-433.65 m: Every five metres 433.65-TD: Every two metres
**Cored sections:**----
**Geophysical logs:** 486.65-TD: Gamma Ray, Caliper, Dual Guard-Forxo log. Compensated Acoustic log.

### Skälsåker-1

**Location:** 1350 m NW of the centrum of the village of Värpinge,150 m N of the road to Önnerup.
**Coordinates:** 55°42'66"N 13°07'86"E X 617904 Y 133172
**Total depth:** 687.66 m b sl
**Elevation:** 13.34 m a sl (KB)
**Lund Sandstone:** 496.66-TD
**Samples:** 0-574.66 m: Every three metres 574.66-TD: Every meter
**Cored sections:** 586.16-595.16 m
**Geophysical logs:** 0-570.66 m: Gamma Ray, Single Point Resistivity 536.66-684.66 m: Gamma Ray, Neutron Porosity log

### Skälsåker-2

**Location**: 1350 m WNW of the centrum of the village of Värpinge immediately on the N side beside the road to Önnerup.
**Coordinates**: 55°42'53''N 13°07'74''E X 617870 Y 133164
**Total depth**: 655.46 m b sl
**Elevation**: 13.04 m a sl (KB)
**Lund Sandstone**: 523.96-TD
**Samples**: 0-523.96 m: Every three metres 523.96-TD: Every meter
**Cored sections**:-----
**Geophysical logs**: 0-522.96 m: Gamma Ray (inside casing) 552.96-652.96 m: Gamma Ray, Acoustic, Caliper, Dual Guard-Forxo

### Hansagården-1

**Location**: 1900 m W of the village of Värpinge immediately on the N side of the road to Önnerup.
**Coordinates**: 55°42'58''N 13°07'37''E X 617884 Y 133119
**Total depth**: 696.8 m b sl
**Elevation**: 13.2 m a sl (KB)
**Lund Sandstone**: 528.8-TD
**Samples**: 0-61.8 m: No recovery 61.8-436.8 m: Every five metres 436.8-TD: Every two metres
**Cored sections**:-----
**Geophysical logs**: 64.3-570.3 m: Gamma Ray, Caliper, Dual-Guard-Forxo log. 569.3-TD: Gamma Ray, Caliper, Dual-Guard-Forxo log, Compensated Acoustic log

### Norrevång-1

**Location**: 2260 m N of the church of Löddeköpinge.
**Coordinates**: 55°46'46''N 13°01'28''E X 618686 Y 132536
**Total depth**: 2096.8 m b sl
**Elevation**: 17.20 m a sl (KB)
**Lund Sandstone**: 688-1268 m
**Samples**: Every three metres
**Cored sections**: No cores were cut within the Campanian sequence.
**Geophysical logs**: 61.8-2096.8 m: Induction-Electrical 61.8-2095.8 m: Borehole Compensated Sonic log, Gamma Ray 1632.8-2096.8 m: Sidewall Neutron Porosity log, Formation Density log, Proximity log 61.8-1832.8 m: Caliper

### Mossheddinge-1

**Location**: 6.5 km SSW of Dalby
**Coordinates**: 55°36'55''N 13°18'21''E X 616792 Y 134236
**Total depth**: 1784.94 m b sl
**Elevation**: 36.06 m a sl (KB)
**Lund Sandstone**: 580-890 m
**Samples**: 0-51 m: No recovery 51-TD : Every three metres
**Cored sections**: -----
**Geophysical logs.**: 213-1784.94 m: Induction Electrical Survey (IES), Sonic log (BHC), Gamma Ray, Spontaneous potential, Caliper.

### Svedala-1

**Location**: 65 m N of Sege stream, 750 m S of Svedala church
**Coordinates**: 55°30'65''N 13°14'05''E X615593 Y 133715
**Total depth**: 1674 m b sl
**Elevation**: 47 m a sl (KB)
**Lund Sandstone**: 693-717 m
**Samples**: -------
**Cored sections**: 0-1674 m
**Geophysical logs.**: Data missing

### Barsebäck-1

**Location**: Referring to the coordinates
**Coordinates**: 55°44'49''N 12°55'42''E X 618370 Y 131880
**Total depth**: 2254.9 m b sl
**Elevation**: 8.1 m a sl (KB)
**Lund Sandstone**: 486.9-863.9 m
**Samples**: 486.9-863.9 m Every three metres
**Cored sections**: No cores were cut within the Campanian sequence
**Geophysical logs**: 141.9-2173.9 m: Induction Electrical Survey, Proximity log, Gamma Ray, Bore-Hole Compensated Formation Density Compensated, Sidewall Neutron Porosity.

### Nyhem-1

**Location**: Referring to the coordinates
**Coordinates**: 55°43'47''N 12°51'43''E X 619960 Y 131570
**Total depth**: 1065 m b sl
**Elevation**: 15.0 m a sl (KB)
**Lund Sandstone**: 610-1065 m
**Samples**: 610-1065 m Every three metres
**Cored sections**: -----
**Geophysical logs**: 0-TD: Temperature, Caliper. 0-630: Single Point Resistance 0-750: Gamma Ray 0-770: Sonic

## LITHOLOGICAL DESCRIPTIONS

### Kyrkheddinge-1

**402-422**: Medium to coarse calcareous sandstone. Quartz averages 70-80%. Occasional beds rich in fossil debris (bivalves, echinoderms, brachiopods). Large- tested orbitoid foraminifers relatively common in coarse sand-beds. General fining upward trend but individual beds of coarse sand interrupt this trend in the upper part. Coal as debris fragments scattered in the sand. Glauconite as uniformly occurring pellet-like aggregates. The unit is dominantly unconsolidated or poorly cemented with calcite. A hard calcite cemented calcareous sandstone between 410 - 416 m.

**422-434**: Arenaceous and argillaceous bioclastic limestone. Glauconite and pyrite common.

**434-458**: Fine to medium calcareous sandstone. Poorly consolidated, frequently unconsolidated. Calcite and rarely silica cemented. Single beds rich in coal-debris and glauconite.

**458-480**: Arenaceous and argillaceous limestone. Increasingly argillaceous towards basal part. Basal 12 metres therefore more precisely described as calcareous mudstone. Macrofossils common.

**480-489**: Medium sandstone. Well consolidated. Cemented with calcite and silica. Scattered glauconite pellets.

**489-535**: Mainly argillaceous and arenaceous grey limestone alternating with beds of calcareous mudstone. Rare thin interbeds of fine calcareous sandstone. Glauconite, pyrite, coal. Coal especially at 505-517 m.

**535-601**: Medium to coarse calcareous sandstone. Moderately well consolidated. Calcite cement. Fossil fragments uncommon. Somewhat argillaceous matrix. Pyrite.

**601-615**: Argillaceous, arenaceous and biomicritic limestone. Thin interbeds of medium calcareous sandstone relatively common. Glauconite and coal frequent throughout the unit and at 600 m as thin laminae dipping approximately 10 degrees.

**615-620**: Fine to medium, poorly consolidated sandstone. Glauconite, coal common. Alternating beds of argillaceous and biomicritic limestones.

**620-656**: Arenaceous, argillaceous and biomicritic limestone. Various amounts of glauconite and pyrite.

**656-662**: Medium, occasionally fine calcareous sandstone. Mainly poorly consolidated. Unconsolidated beds frequent. Sparry calcite cement.

**662-669**: Mainly fine argillaceous and fine sandy limestones, calcilutitic. Layering thin, irregular in parts with mottled or bioturbated texture. Quartz content commonly 10-20%, occasionally higher. Scattered macrofossils, bivalves, bryozoans etc. fairly common in less quartz rich intervals. Sandstone at 665-667 m consisting of fine to medium, variably calcareous quartzose sandstone, mainly poorly cemented, occasionally well cemented with calcite and silica. Basal parts laminated with thin calcareous and coal/clay rich layers. Isolated decimeter thick sheets of very calcareous sandstone occur within otherwise limestone dominated unit at 663 m (weak indications of rippled upper part) and at 667 m. The latter grades basally into the limestone interval, through increasing sand content into clay/coal rich, glauconitic and laminated fine-grained sandstones (see below).

**669-687**: Mainly fine to medium, somewhat calcareous quartzose sandstone and sand. Sandstone generally poorly cemented with calcite, occasional thin irregular bands of silica cemented hard sandstone. Thin beds of very calcareous sandstone frequently contain many macrofossil fragments (mainly bivalves, brachiopods, bryozoans). These thin beds have a sharp base and are generally fining upwards. Detrital glauconite common. Two intervals of calcilutitic argillaceous, silty, and sandy limestones at 698-699 and 702-703 m grade into laminated, glauconitic and clay rich, fine to medium calcareous sandstones, with upper and lower contacts showing decreasing and increasing quartz content.

**687-700**: Dominantly fine, argillaceous, silty and fine sandy calcilutitic limestone, with thin and irregular layering or bioturbated texture. Occasional large burrows. Scattered macrofossils (bryozoans, bivalves and articulate brachiopods etc.). Variable quartz content, mainly 10-20% but some thin (<10 cm) quartz-rich beds occur particularly in the basal part. Thicker sandstone intercalations occur as follows: 689-690.5 m: horizontally laminated clay and coal, rich fine to medium, calcareous sandstone moderately consolidated, with patchy calcite cement. 693-693.6 m: medium, very calcareous sandstone with macrofossil fragments and with sharp upper boundary, passing down into less calcareous, glauconitic and clay rich, fine to medium sandstones with horizontal lamination, picked out by dark clay and coal rich laminae, and with transitional lower boundary. 697-697.5 m: Laminated, upward fining sand with erosional base, representing small channel consisting of fine to medium, calcareous sandstone, with glauconitic, clay and coal rich laminae common in upper more thinly laminated part. 697.5-699 m: laminated and upward fining sand with sharp base, consisting of well consolidated, very calcareous medium sandstone passing up into less calcareous sandstone with rip-up-mudclasts in upper part, and then into laminated, fine sandy limestone with upward fining, low angle foresets.

**700-711**: Fine to medium, variably calcareous quartzose sandstone and sand. Mainly poorly consolidated, particularly in upper parts.

Uppermost 0.8 m comprising upward fining unit, with low angle cross-bedding in lower part passing up into laminated, clay coal rich sandstones. Detrital glauconite and coal common accessory minerals throughout.

**711-739**: Fine, argillaceous and fine sandy limestone. Layering thin, irregular, some parts with bioturbated, mottled texture. Clay-rich laminae generally also glauconitic, occasionally coal rich. Macrofossils frequent, (bivalves, bryozoans, belemnites, echinoderms etc.). Thin beds (<10 cm) occasionally interrupt the limestone strata. At base 1 m well consolidated, very calcareous, medium, silica cemented sandstone passing up into dark, argillaceous, glauconitic, fine to medium and poorly consolidated sandstone. Upper and lower boundaries transitional. At 736 m an approximately 0.5 m thick fine to medium and well consolidated sandstone, argillaceous, glauconitic and composed of several fining-up sets with clay and coal rich upper portions; occasional convolute laminations.

**739-757**: Fine to medium, somewhat calcareous quartzose sandstone and sand. Mainly poorly consolidated. Calcite cemented Intervals of dark, clay rich beds with thin clay coal laminae. Glauconite, coal and mica main accessory minerals. Occasional thin beds of silica cemented very hard medium sandstone as thin interbeds. Upward fining, laminated sand sheets having sharp basal boundaries at 748.8-750 m and 751.3-751.7 m. Intercalations of fine argillaceous sandy limestone mostly thin, transitional to dark, argillaceous, fine, coal-rich laminated sandstone. Thicker limestone at 736.2-738.9 m and 749-750.9 m, comprising thinly and wispy layered calcilutites, with numerous thin sandy laminae. Clay/coal and micaceous laminae also frequent. Marine macrofossils occasionally frequent (brachiopods, echinoderms, bivalves, bryozoans etc.). In the upper limestone 3 hard carbonate rich 0.5 m thick medium-grained sandstone sheets, with erosional lower boundaries, fining upwards, indications of cross-bedding and ripples in top 10 cm. Upper boundary generally transitional. The lower limestone includes an approximately 0.5 m thick hard, very calcareous medium sandstone which has minor clay filled oblique fractures and in the basal part small clay-clasts.

**757-777**: Fine to medium, argillaceous, glauconitic, coal-rich sandstone. Poorly/moderately consolidated, calcite cemented. Frequently calcareous, in parts fine laminated. Glauconite, mica, coal frequent as accessory detrital minerals. Interbeds of fine, argillaceous, sandy calcilutite (< 1 m in thick) with transitions through dark, clay/coal rich fine sandstones. Occasional beds of well consolidated, calcite cemented, very calcareous, medium sandstone. These represents basal portion of upward-fining sand sheet. Sharp based, laminated, with weak cross-bedding. In the basal part of the interval, a number of such units pass upwards from basal hard, calcareous, laminated sand through less calcareous sandstone into thinly laminated, clay and coal rich, fine to medium sandstone, finally into fine, argillaceous, sandy limestone.

**777-786**: Medium, slightly calcareous quartzose sandstone and sand alternating with dark, laminated, fine to medium, clay and coal rich sandstone. Some well consolidated, calcite cemented, medium sandstones with scattered gravel grains.

**786-796**: Dominantly argillaceous, silty and fine sandy calcilutitic limestone, with thin, irregular layering and occasional mottled texture. Glauconitic and clay rich, locally with coal-rich laminae. Scattered bivalves, echinoderms, bryzoans. Interval of medium, calcareous sandstone. Friable or poorly consolidated, calcite cemented between 789 and 791 m. Erosional basal boundaries in several thin sand sheets that are fining upward; upper parts usually rippled and cross-bedded. Thin mica and glauconite-rich laminae occasionally in upper parts of these units.

**796-810**: Fine to medium, somewhat calcareous quartzose sandstone. Variably argillaceous with dark, laminated, clay and coal-rich, mainly friable or poorly consolidated layers. Occasional well consolidated beds cemented with calcite, together with thin argillaceous, sandy limestone. Approximately 1 m thick beds frequently sharp based and fining upwards, occasionally with a rippled upper part. Very calcareous sandstone at 809.5-809.8 m, somewhat conglomeratic, with small rounded pebbles of quartz.

**810-819**: Fine to medium, argillaceous, glauconitic, slightly calcareous sandstone, mainly friable or poorly consolidated, occasionally calcite cemented. Common intervals of dark laminated clay and coal rich beds, and intercalations of argillaceous, sandy limestone having narrow, irregular layering. Some hard, calcareous beds among the sandstone. Upward fining calcareous sand sheets, with horizontal dark, clay- and coal-rich lamination, at 815.3-815.6 m, 816-816.5 m, 817-817.3 m, and 817.9-818 m.

## Kyrkheddinge-2

**322-365**: Coarse to very coarse, calcareous, sand and moderately consolidated sandstone. Occasional well consolidated beds are mainly cemented frequently also with silica. Occasional thin beds of of sandy biocalcarenite with up to 40% skeletal debris. The interval is fining upward. Significant argillaceous mat ix in upper beds. Glauconite, coal common. Coal particularly common in uppermost part.

**365-377**: Argillaceous, silty, and fine sandy limestone, calcilutitic, glauconite, thin interbeds of sandier limestone. Scattered bivalves, brachiopods.

**377-526**: Medium to coarse, occasionally very coarse, calcareous, slightly argillaceous sand, and poorly consolidated sandstone. Cemented with calcite and silica when well consolidated.

Interbeds of biocalcarenitic sand. Detrital coal commonly together with glauconite. Well consolidated beds relatively common in lower 40 m.

**526-538:** Alternating medium, calcareous, argillaceous sandstone, and argillaceous, fine sandy limestone. Interbedded with medium, calcareous sand (< 1 m). Glauconite, coal, pyrite.

**538-583:** Fine to medium, calcareous, argillaceous, moderately consolidated sandstone. Poorly cemented with calcite. Glauconite, pyrite. Boundaries indistinct.

**583-608:** Mainly fine sandy, calcareous limestone. Fine calcareous, moderately consolidated sandstone interbeds. Calcite cemented. Occasional thin unconsolidated medium sand, somewhat argillaceous and calcareous, with transitional lower boundaries.

**608-652:** Fine to medium, calcareous, somewhat argillaceous, poorly consolidated sandstone and sand. poorly cemented with calcite, occasionally silica. Detrital coal, glauconite, common accessory minerals.

**652-710:** Fine to medium, calcareous, sandstone. Moderately consolidated, generally calcite cemented, thin beds occasionally with silica. Passing down into sandy, argillaceous limestone alternated by variably indurated sandstones.

**710-740:** Fine to medium, argillaceous, calcareous, poorly to moderately consolidated sandstone. Calcite cemented. Glauconite, coal common.

**740-789:** Medium, very silty, fine sandy, argillaceous, calcilutitic limestone. Thinly, irregularly layered, or with mottled fabric. Scattered fragments, mainly bryozoans and bivalves. Alternatingly fine to medium-grained, slightly calcareous quartzose sandstone, variably argillaceous, mostly poorly consolidated and calcite cemented, Occasional beds of silica cemented sandstone. Glauconite, coal, common accessory detrital minerals. Pyrite in argillaceous limestone beds.

**789-805:** Fine to medium, slightly calcareous, quartzose, variably argillaceous, poorly to moderately consolidated sandstone. Interbeds of sandy irregularly layered limestone, occasionally rich in organic matter.

**805-820:** Fine, very argillaceous, silty, sandy limestone. Alternating with pure limestone. Some intercalations of fine, calcareous, argillaceous sandstone, Glauconite, pyrite, coal relatively common.

**820-859:** Fine to medium, somewhat calcareous, argillaceous sandstone. Generally moderately consolidated. Calcite cemented. Detrital coal, glauconite common.

**859-867:** Fine, very argillaceous, calcilutitic, silty limestone. Glauconite, pyrite common.

## Kyrkheddinge-3

**471-523:** Fine to coarse, variably calcareous sands and sandstone, Poorly or moderately consolidated, calcite cemented. Thin beds hard, silica cemented. The unit is fining upward. Detrital coal, glauconite common. Scattered bivalves, brachiopods, bryozoans.

**523-544:** Silty and fine sandy, very argillaceous bioturbated limestone. Glauconite, mica, pyrite common Interbeds of calcareous claystone ifrequent.

**544-559:** Medium, somewhat calcareous, sandstone. Moderately consolidated. Occasionally well consolidated beds cemented with calcite and pyrite. Glauconite, coal varies.

**559-643:** Somewhat silty, fine sandy, very argillaceous limestone. Pyrite, glauconite common accessory minerals. Interbeds of calcareous claystone and clay. Occasional beds more arenaceous.

**643-673:** Calcareous, silty fine sandy, argillaceous limestone. The basal parts dominated by claystone. Homegeneous with only occasional arenaceous beds. Glauconite, mica, pyrite common.

**673-697:** Argillaceous limestone interbedded by somewhat calcareous, fine to medium quartzose sandstone and sand. Poorly consolidated. Occasional hard beds cemented with silica or calcite. Interbeds of argillaceous limestone with glauconite and pyrite.

**697-769:** Argillaceous, silty and fine sandy limestone. Interbedded with calcareous sandstone. Gradual changes between varying content of clay and sand, characteristic wispy layering occasionally. Pyritised burrows.

**769-839:** Clastic intervals at 769-782, 791-801 and 810-818 m consisting of calcareous, fine to medium quartzose sand and sandstone. Mainly poorly consolidated, cemented with calcite. Bivalves, brachiopods, bryozoans. Basal interval with gradual increase in argillaceous matrix, transitional into underlying argillaceous limestone. Coal, glauconite. Fine, argillaceous, silty and fine sandy limestone, interbeds the clastic members. The limestone irregularly layered or mottled, burrowed. Scattered fossils, mainly bivalves. Glauconite, minor pyrite, relatively commonly in these interbeds.

**839-872:** Very calcareous, silty, somewhat sandy claystone, thinly laminated, alternating with very argillaceous, silty, fine sandy limestone with mottled texture and relatively muchin glauconite, pyrite, scattered microfossils. Thin calcareous fine to medium sand and sandstone interbeds with some glauconite and coal.

## Kyrkheddinge-4

**382-445:** Medium to coarse, somewhat calcareous, sand and sandstone, generally poorly consolidated, calcite cemented. Occasional silica cemented sandstone. Macrofossils especially common in coarse beds. Detrital coal, glauconite common in upper part. Interbeds of matrix rich sandstone common in basal part. Overall fining upwards.

**445-530**: Mainly medium somewhat calcareous, sand and sandstone, poorly consolidated, variably cemented with silica. A few conglomeratic beds. Occasional well consolidated beds are mainly cemented with silica. The sand has somewhat argillaceous matrix which constitute 10-15% of the fabric. Glauconite and coal common.

**530-567**: Mainly silty, sandy, occasionally argillaceous limestone, mottled, bioturbated. Macrofossils common, brachiopods, bivalves, echinoderms.

**567-630**: Medium sand and sandstone, variably consolidated, calcite or silica cemented. Detrital coal, glauconite, common. Thin interbeds of sandy limestone.

**630-680**: Alternating argillaceous limestone, calcareous sand and sandstone as above. Basal 15 m dominated by sand.

**680-780**: Medium calcareous sand and sandstone. Consolidation varies, consolidated beds mainly cemented with calcite and rarely silica. Silty, sandy, argillaceous limestone at 691-702, 710-730, 735-740, 765-770 m. Limestone in basal part, occasionally rich in organic matter, very argillaceous, grading frequently into calcareous claystone.

**780-840**: Silty, sandy, variably argillaceous limestone, occasionally grading into calcareous claystone, frequently rich in organic matter, frequently interbedded with thin beds of medium sand and sandstone. Basal parts increasingly heterogeneous.

## Kyrkheddinge-5

**415-431**: Medium, somewhat calcareous sand and sandstone, mainly poorly consolidated, calcite cemented. Coarse intervals occasionally rich in bivalves, brachiopods, echinoderms. Detrital coal, glauconite. Thin interbeds of hard, medium sandstone, cemented with silica and calcite.

**431-441**: Sandy, silty, somewhat argillaceous limestone, interbeds of medium sandstone. The latter generally moderately consolidated, calcite cemented, clay varies. Glauconite, coal, common.

**441-515**: Medium to fine, well sorted sand, occasionally cemented with calcite or silica. Frequently interbedded with sandy limestone at 466-481 and 490-495 m. Coal (10%) at 442-447 m, indicating thin bed of coal. Mainly bivalves and bryozoans common.

**515-530**: Alternating sand and limestone as above.

**530-588**: Silty, sandy, occasionally very argillaceous limestone, generally mottled texture, occasionally wavy non-parallel banding. Glauconite, pyrite, coal. Interbeds of medium, somewhat calcareous sand, moderately consolidated, calcite cemented. Glauconite, coal common. Coal layer at 566-569 m. Thicker bed of medium to fine sand at 564-578 m.

**588-634**: Medium, quartzose sand, occasionally calcite cemented, rarely silica. Glauconite and coal traces. Coal between 601-607 m.

**634-646**: Sandy, silty, very argillaceous limestone and calcareous mudstone, occasionally rich in organic matter. Interbeds of thin medium, somewhat calcareous, moderately consolidated sandstone, calcite cemented. Traces of glauconite and coal throughout.

**646-663**: Fine, calcareous sand and sandstone, slightly silty, moderately consolidated, calcite cemented. Matrix slightly argillaceous and calcareous. Interbeds of sandy, silty, argillaceous, occasionally very argillaceous limestone. Glauconite, coal common in both lithologies.

**663-682**: Silty, fine sandy, very argillaceous limestone, frequently grading into pure limestone. Thin interbeds of poorly sorted sandstone. Organic content frequently high.

**682-707**: Fine, calcareous sandstone, slightly silty, poorly or moderately consolidated, mainly calcite, occasionally silica cemented. Alternating beds of poorly sorted, calcareous mudstone and silty, sandy limestone. Traces of pyrite and glauconite in both lithologies.

**707-709**: Silty, fine sandy, somewhat argillaceous limestone. Scattered marine fossils. Wavy non-parallel lamination. Traces of glauconite and coal.

**709-720**: Medium, slightly calcareous sand. Traces of coal, glauconite, pyrite, mica. Interbeds of silica cemented sandstone.

**720-734**: Sandy, silty, argillaceous limestone, occasionally very argillaceous and rich in organic material. Traces of glauconite, coal, pyrite. Thin interbeds of fine to medium, calcareous, occasionally argillaceous moderately consolidated sand and sandstone. Calcite, occasionally silica cemented. Traces of coal.

## Kyrheddinge-6

**352-375**: Medium, well sorted, somewhat calcareous sand. Frequently coarse, rich in bioclasts. Traces of glauconite and feldspar. Thin interbeds of medium, moderatley consolidated sandstone mainly with calcite, less commonly silica cement.

**375-422**: Medium, calcareous sandstone. Moderately and poorly consolidated. Traces of glauconite, coal, feldspar. Alternating with unconsolidated sand. Thin interbeds of sandy and silty limestone.

**422-438**: Sandy, silty and somewhat argillaceous limestone. Glauconite, coal common. Coaly bed at 436-438 m. Interbeds of sand.

**438-509**: Dominantly medium, well sorted sand. Traces of glauconite and coal. Thin beds of medium somewhat calcareous sandstone. Limestones as intercalations at 465-485 m.

**509-545**: Medium to coarse, well sorted sand. Moderately-poorly consolidated. Calcite cemented. Thin interbeds of sandy silty and calcite cemented sandstone with intercalations of very hard silica cemented medium sandstone. Glauconite, coal common.

**545-560**: Silty, sandy, somewhat argillaceous limestone. Traces of coal, pyrite. Alternated by fine sandy, somewhat argillaceous siltstone. Thin clay interbeds. Rich in organic material.

**560-637**: Thick dominantly coarse clastics of medium and coarse slightly calcareous sand and sandstone, occasionally cemented with calcite and silica. Detrital coal, glauconite common.

**637-692**: Heterogeneously alternating fine to medium, silty, somewhat argillaceous, calcareous sand and sandstone, and sandy, silty, argillaceous limestone. Traces of glauconite, coal. Thin beds of fine sandy, calcareous, and argillaceous siltstone at 545-560 m.

**692-705**: Silty, occasionally fine sandy and argillaceous limestone. Traces of glauconite, pyrite. Thin interbeds of siltstone as above.

**705-719**: Medium to fine, well sorted sand. Occasionally cemented with calcite. Traces of coal, glauconite.

**719-740**: Fine sandy, silty, variably argillaceous, limestone with laminae of organic material intercalated with silty lenses (lenticular bedding) and irregular laminae and mottled texture due to bioturbation. Thin interbeds of medium, silty, calcareous sandstone. Moderately consolidated with calcite occasionally with silica cement. Glauconite, coal scattered throughout interval except where coal occurs as laminae. Pyrite nodules in beds of argillaceous limestone.

**740-784**: Medium to fine, variably calcareous, moderately sorted sand and sandstone. Poorly or moderately consolidated. Calcite cemented Occasionally with silica. Thin interbeds of sandy limestone. Traces of glauconite, coal.

**784-792**: Silty, sandy, argillaceous limestone alternating with fine calcareous and silty sandstone. Thin interbeds of very sandy limestone.

**792-805**: Fine to medium, somewhat calcareous sand and sandstone. Poorly consolidated. Calcite cemented. Glauconite, coal traces.

**805-881**: Heterogeneously alternating sand, sandstone and limestone, variably argillaceous and silty, loose to well consolidated, calcite and silica cemented. Glauconite, coal common. Thicker sand beds at 819-825 m, 850-863 m, 875-881 m.

**881-894**: Fine sandy, silty very argillaceous limestone. Traces of glauconite, coal. Thin interbeds of medium, calcareous, moderately to well consolidated sandstone, frequently cemented with calcite and silica.

**894-906**: Uniformly fine to medium well sorted sand. Traces of glauconite, coal.

**906-919**: Similar lithology as in 881-894 m.

**919-943**: Like 894-906 m.

**943-970**: Like 881-894 m but slightly more glauconite.

**970-995**: Well sorted sand as in 919-943 m.

**995-1009**: Silty, sandy, argillaceous limestone. Glauconitic, occasionally very argillaceous grading into claystone. Interbeds of clay.

## Kyrkheddinge-7

**331-368**: Medium to coarse quartzose sand. Occasionally poorly consolidated sandstone. Bioclasts common in coarse beds. Glauconite, coal common.

**368-388**: Silty, fine sandy, somewhat argillaceous limestone. Occasionally very sandy. Interbeds of fine to medium sand.

**388-414**: Medium somewhat calcareous sand and sandstone. Glauconite, coal common.

**414-424**: Silty, slightly fine sandy, argillaceous limestone. Frequent interbeds of calcareous sandstone. Thin sands interbeds as above. Glauconite, coal. Occasional bioclasts, mainly bivalves.

**424-524**: Medium to coarse sand and sandstone. Mainly poorly consolidated, calcite or silica cemented. Thin beds of coal-rich sand. Bioclasts occasionally common in coarse beds.

**524-539**: Silty, fine sandy, variably argillaceous limestone. Alternating with calcareous, fine, argillaceous sandstone. Mainly moderately consolidated, calcite cemented. Pyrite, coal, glauconite occasionally common. Thin interbeds of fine, calcareous sandstone.

**539-636**: Medium sand. occasionally poorly consolidated sandstone, calcite cemented, with significant amount of glauconite.

**636-653**: Like 524-539 m

**653-680**: Medium to coarse sand, occasionally calcite cemented. Traces of glauconite, coal.

**680-699**: Silty, frequently very argillaceous, occasionally fine sandy limestone. Glauconite, coal common. Thin clay beds.

**699-717**: Fine, somewhat argillaceous and variably calcareous sandstone. Sand interbeds. Occasionally very silty. Traces of glauconite, coal.

**717-742**: Limestone as in 680-699.

**742-804**: Medium to coarse, slightly calcareous sand. Frequently calcite cemented sandstone, moderately consolidated. Glauconite, coal. Thin interbeds of fine sandy limestone.

**804-835**: Silty, occasionally very silty, fine sandy, variably argillaceous limestone. Traces of glauconite. Alternating with silty, very argillaceous limestone. Beds of calcareous clay. Very thin beds of poorly sorted sandstone.

**835-858**: Fine to very fine, calcareous sand. Occasionally sandstone, calcite cemented. Slightly glauconitic. Alternating beds of limestone as in 804-835 m.

**858-864**: Limestone as in 804-835 m.

**864-896**: Fine to very fine sand. Occasionally moderately consolidated sandstone cemented with calcite. Interbeds of silty, sandy, very argillaceous limestone at 879-880, 887-888, and 889-890 m.

**896-946**: Dominantly silty, very argillaceous limestone. Thin beds of very fine, poorly sorted sand. Glauconite, pyrite.

**946-958**: Fine, well sorted quartzose sand.

**958-980**: Alternating limestone, and sand as in 896-946 m.

**980-1002**: Medium to coarse quartzose sand. Numerous bioclasts, mainly bivalves, bryozoans.

**1002-1041**: Thin beds of fine to medium sand interbedded with silty, argillaceous limestone. Thin beds of claystone .

**1041-1084**: Medium to fine, variably calcareous, argillaceous sand and sandstone alternating with argillaceous, silty limestone. Glauconite common, frequently colouring the sediment. Bioclasts occasionally common mainly bryozoans.

## Flackarp-1

**519-554**: Coarse to medium, somewhat calcareous sand and sandstone. Poorly consolidated, calcite cemented. Thin interbeds of argillaceous, somewhat sandy limestone. Traces of glauconite, coal, throughout. Overall coarsening upwards. Upper metres polymict composed of poorly sorted material older paleozoic and mesozoic sediments, feldspars, bioclasts etc.

**554-582**: Occasionally very argillaceous limestone. Mottled texture. Glauconite common. Thin interbeds of calcareous, medium sandstone moderately consolidated, calcite cemented. Glauconite traces.

**582-585**: Medium to coarse somewhat calcareous poorly consolidated sandstone.

**585-597**: Very argillaceous, silty, somewhat sandy limestone occasionally rich in organic material especially in the upper metres. Traces of pyrite.

**597-623**: Limestone as above but with lower content of organic material, occasionally fine sandy, silty. Less argillaceous.

**623-628**: Medium, uniform sand.

**628-638**: Argillaceous, fine sandy, silty limestone. Glauconite, coal. Pyrite traces.

**638-645**: Medium, somewhat calcareous sand with interbeds of moderately consolidated sandstone, silica and calcite cemented. Glauconite traces.

**645-748**: Mainly medium to fine sand and sandstone. Occasionally calcareous, moderately sorted. Glauconite,coal debris frequent. Interbedded and alternating with argillaceous, silty, sandy limestone. occasionally claystone and pure clay. Thin beds occasionally rich in organic material. Glauconite common in limestone. Thick limestone/claystone intervals at 644.5-647.5, 654-667, 685-693, 701-706 m.

**748-762**: Argillaceous to very argillaceous, sandy and silty limestone, frequently rich in organic material. Pyrite traces.

**762 -802**: Medium to fine sand and sandstone, moderately sorted, poorly consolidated. Interbeds of argillaceous limestone.

## Värpinge-1

**410-439**: Medium to coarse, occasionally very coarse, somewhat calcareous, polymict sand and sandstone. Friable, poorly cemented with calcite. Thin interbeds of moderately consolidated sandstone. Glauconite, feldspar, rockfragments, coal, brachiopods, bryozoans, bivalves, echinoderms are common.

**439-471**: Silty, somewhat sandy, argillaceous limestone. Interbedded with calcareous, sandy siltstone. Thin beds of medium sand.

**471-485**: Medium to coarse, frequently conglomeratic (gneiss-, granite, schist, shale, quartzite and ironstone fragments) sand, throughout. Traces of glauconite, coal.

**485-498**: Like 439-471 m.

**498-526**: Medium to coarse sand. Rich in mainly bivalves, echinoderms, bryozoans, brachiopods. Traces of coal, glauconite.

**526-536**: Argillaceous and fine silty, occasionally very argillaceous limestone. Glauconite, pyrite traces. Wavy non parallel banding. Bioturbated.

**536-545**: Medium to fine, occasionally coarse fossiliferous sand. Coal traces in basal part.

**545-559**: Argillaceous, silty, occasionally very argillaceous limestone. Pyrite traces.

**559-568**: Medium, well sorted sand. Interbedded with sandy limestone and hard calcite and silica cemented sandstone. Traces of coal, glauconite.

**568-645**: Medium to fine, variably calcareous and silty sand alternating with argillaceous, silty, fine sandy limestone. Thin beds of well consolidated sandstone, Silica cemented. Traces of coal, glauconite.

**645-670**: Clean quartzsand. Medium to coarse, frequently conglomeratic. Traces of detrital coal.

**670-703**: Argillaceous to very argillaceous limestone. Alternating with silty, fine sandy limestone and fine sandy, siltstone. Glauconite, pyrite. Occasional clay beds.

**703-751**: Uniform medium to fine sand alternating with argillaceous, silty and fine sandy limestone. Thin beds of clay. Glauconite, coal, traces.

## Värpinge-2

**446-451**: Medium to coarse sand, mainly poorly sorted. Feldspars, rockfragments, glauconite. Occasional layers rich in bioclasts.

**449-462**: Fine, frequently argillaceous, silty sandstone. Interbedded with silty, fine sandy limestone. Glauconite, pyrite traces.

**462-494**: Sandstone and limestone as above. Frequently interbedded with medium, calcareous sandstone, generally well consolidated, calcite cemented. Minor beds of medium sand.

**494-517**: Medium to coarse, somewhat calcareous sand, mainly poorly sorted. Thin beds of medium calcareous sandstone, moderately or well consolidated, calcite and silica cemented.

**517-527**: Very calcareous, fine sandy siltstone. Frequently argillaceous. Interbedded with argillaceous, silty limestone. Traces of glauconite.

**527-539**: Medium to fine, variably calcareous sand. Thin beds of calcareous silty sandstone. Traces of well consolidated sandstone, cemented with silica.

**539-549**: Argillaceous, silty, fine sandy limestone. Interbedded with very calcareous argillaceous and silty sandstone.

**549-567**: Medium to coarse, occasionally fine, variably calcareous, argillaceous sand. Minor beds of medium sandstone, generally well consolidated, cemented with calcite and/or silica. Traces of glauconite, detrital coal.

**567-591**: Sandstone like 549-567 m, alternating with limestone like 517-527 m. Minor beds of sand.

**591-602**: Very argillaceous, calcareous, slightly glauconitic, fine sandstone. Traces of pyrite.

**602-610**: Medium to coarse quartzose sand, frequently calcite cemented.

**610-620**: Sandstone alternating with limestone and minor beds of sand.

**620-636**: Medium to coarse, variably calcareous sand, and calcite cemented sandstone.

## Värpinge-3

**447-457**: Medium, occasionally coarse, poorly sorted sand. Fragments of iron-rich Jurassic sandstone, Cambrian quartzite and crystalline rocks. Increasing grain-size towards basal part. 1 m thick bed at 451 m is fairly rich in coal debris.

**457-483**: Argillaceous, variably silty, calcareous and fine sandstone. Minor glauconite, coal. Traces of clay-rich beds.

**483-490**: Medium to coarse, well sorted, occasionally poorly sorted, very coarse sand. Minor non-quartz components as at 447-457 m. Traces of kaolinitic matrix in basal part.

**490-502**: Argillaceous, variably silty, calcareous, fine sandstone. Alternating with silty and occasionally fine sandy limestone.

**502-509**: Like 483-490 m.

**509-522**: Dominantly silty, very calcareous and fine sandstone. Alternating with silty and sandy limestones, and medium sand.

**522-527**: Medium, variably calcareous sand. Thin interbeds of sandstones, moderately consolidated, calcite cemented with calcite. Indications of kaolinitic matrix. Traces of glauconite, coal.

**527-549**: Mainly sand as above Interbedded with silty, fine sandy limestones. Minor glauconite, coal.

**549-589**: Medium to fine, variably calcareous, argillaceous somewhat silty sand. Interbeds of medium sandstone, moderately consolidated, calcite cemented. Frequently well cemented, very well consolidated. Traces of glauconite. Minor coal. Occasional thin beds of arenaceous limestone.

**589-614**: Mainly limestone/sandstone, alternating with fine to medium, argillaceous, silty, variably calcareous sand. Thin beds of sandstone frequent. Traces of glauconite, pyrite. Minor coal.

## Värpinge 4

**407-436**: Medium to coarse sand, mainly subrounded, clear and frosted quartz-grains. Poorly sorted. Feldspar, rockfragments, glauconite, occasionally rich in bioclasts.

**436-476**: Mainly sand as above but dominantly medium. Interbedded with silty, sandy, argillaceous limestone. Generally moderately hard, occasionally very hard, microcrystalline.

**476-487**: Silty and fine sandy, somewhat argillaceous, hard to very hard, glauconitic limestone. Alternating with calcareous, silty, occasionally somewhat argillaceous sandstone. Coal traces. Minor beds of fine to medium calcareous sandstone, moderately consolidated, occasionally very well consolidated Calcite cemented.

**487-492**: Medium to coarse sand. Well sorted. Partly polymict.

**492-518**: Sand as at 407-436 m, frequently interbedded with medium to fine, calcareous sandstone, moderately and well consolidated. Calcite and silica cemented.Coal, glauconite traces.

**518-530**: Fine to medium, somewhat calcareous sand. Less frequently interbedded with indurated sandstone as above.

**530-586**: Sand as above but interbedded with argillaceous, sandy siltstones. Mostly poorly consolidated and calcite cemented.

**586-600**: Fine to medium sand. Moderately sorted. Free of cement or matrix. Interbeds (maximum 0.5 m thick) of hard calcite and silica cemented sandstone.

**600-649**: Fine to medium, silty, argillaceous sand. Frequently alternating with fine sandy silt and clay. Occasional interbeds of sandstone as above.

**649-656**: Fine to coarse sand and sandstone as above. Interbedded with silty, sandy, somewhat argillaceous limestone.

## Skälsåker-1

**497-510**: Coarse to very coarse, occasionally conglomeratic and polymict sand (feldspar, rockfragments, bivalves, bryozoans). Somewhat glauconitic in the basal part.

**510-513**: Silty, fine sandy, argillaceous limestone alternating with calcareous argillaceous, fine sandy siltstone.

**513-528**: Coarse, occasionally conglomeratic sand. Interbedded with coarse calcareous sandstone. Well consolidated, cemented with silica and calcite. Thin beds of argillaceous limestone as above. Traces of glauconite.

**528-532**: Mainly argillaceous, calcareous, fine sandy siltstone. Thin interbeds of sandy limestone. Minor amount of coal.

**532-594**: Medium to coarse, somewhat calcareous sand. Traces of glauconite, coal. Interbedded with medium, calcareous, moderately consolidated sandstone. Occasionally well consolidated, then cemented with calcite, occasionally silica. Occasional thin beds of very sandy limestone. Bioclasts common at certain levels, mainly bryozoans.

**594-599**: Argillaceous, calcareous, fine sandstone. Traces of glauconite. Interbedded with medium sand, with minor argillaceous matrix. Occasional very thin layers of medium, calcareous sandstone.

**599-624**: Medium to coarse sand. Well sorted. Minor glauconite, coal. Occasionally interbedded with medium sandstone. Poorly consolidated. Cemented with calcite.

**624-628**: Argillaceous, calcareous, fine sandstone. Traces of glauconite, coal. Minor beds of argillaceous and silty limestone.

**628-652**: Sand and sandstone as above.

**652-659**: Argillaceous, calcareous, very fine sandstone, occasionally very argillaceous. Interbeds of silty, argillaceous, sandy limestone. Glauconite, coal traces

**659-670**: Medium, calcareous, somewhat silty sand. Alternating with medium to fine sandstone, moderately consolidated, calcite cemented, occasionally silica.

**670-689**: Sand/sandstone as above alternating with arenacous limestone.

## Skälsåker-2

**524-555**: Coarse to medium, polymict sand. Minor glauconite, coal. Occasional beds rich in bryozoans and bivalves.

**555-565**: Fine, argillaceous, calcareous sandstone, alternating with beds of silty, argillaceous limestone. Traces of glauconite, pyrite. Minor beds of medium sand. Detrital coal common in occasional sand-beds.

**565-593**: Medium to coarse, somewhat calcareous sand. Traces of glauconite, coal.

**593-599**: Fine, calcareous, variably argillaceous sandstone. Interbedded with silty, argillaceous limestone. Traces of coal, glauconite.

**599-610**: Sand as above.

**610-612**: Sandstone and limestone as at 593-599 m.

**612-637**: Medium, variably calcareous sand. Occasionally poorly consolidated. Patchy calcite cement.

**637-655**: Fine to medium, variably calcareous, silty sand. Minor beds of calcite cemented sandstone. Traces of silica cemented sandstones. Thin beds of very fine sandstone and arenaceous limestone.

## Hansagården-1

**529-543**: Medium to coarse, variably calcareous sand. Occasionally rich in bryozoans. Traces of glauconite, coal.

**543-560**: Very fine, somewhat calcareous sandstone. Calcite cemented. Traces of coal, glauconite. Thin beds of medium sand.

**560-564**: Medium to coarse sand as above.

**564-565**: Very fine, calcareous sandstone. Traces of coal, glauconite.

**565-567**: Medium to coarse sand. Occasional thin layers of gravel. The sand is polymict, (feldspars, rockfragments ironstones, quartzites). Glauconite, coal traces.

**567-572**: Fine to medium-sandy, variably calcareous, argillaceous sandstone. Traces of glauconite, coal, pyrite. Cemented with calcite and silica. Minor beds of medium sand.

**572-592**: Very calcareous, argillaceous, very fine, calcite cemented sandstone. Traces of glauconite, coal.

**592-639**: Fine to medium, variably calcareous sand. Traces of glauconite, coal. Alternating with medium, calcareous, somewhat silty sandstone. Moderately occasionally very well consolidated. Cemented with calcite and silica. Minor beds of very fine, somewhat calcareous, argillaceous sandstone. Traces of glauconite, coal in both lithologies.

**639-643**: Variably argillaceous, variably calcareous, very fine sandstone. Minor beds of argillaceous, silty limestone.

**643-659**: Medium to coarse sand, generally well sorted. Minor beds of calcite cemented sandstone.

**659-668**: Alternating sandstone and sand as above.

**668-687**: Medium, well sorted sand. Minor beds of sandstone as above.

**687-688**: Medium, somewhat silty, variably calcareous sandstone. Moderately consolidated. Calcite and silica cemented. Traces of glauconite, coal.

**688-697**: Fine to medium sand and sandstone as above.

## Norrevång-1

**688-737**: Very fine, calcareous,somewhat argillaceous sandstone, occasionally very silty, frequently passing into sandy limestone. Minor glauconite. Pyrite traces. Conglomeratic bed at 737 m.

**737-754**: Silty, fine sandy, very argillaceous limestone. Traces of glauconite.

**754-784**: Fine, calcareous, somewhat silty sand, alternating with fine sandstone, moderately consolidated, cemented with calcite, slightly glauconitic. Conglomeratic bed at 764 m.

**784-1268**: Grey silty clacareous claystone and clays, interbeds of fine sandstone, calcite cemented, traces of glauconite. Increasingly clayey and glauconitic with depth.

## Barsebäck-1

**487-714**: Soft, very calcareous clay, interbedded with argillaceous, silty limestone and calcareous fine sandstone.

**714-802**: Argillaceous and silty limestone, alternating with calcareous and very fine sandstone. Minor amount of pyrite and glauconite.

**802-819**: Fine to very fine, silty, somewhat calcareous sand and sandstone. Moderately consolidated, calcite cemented. Thin clay interbeds. Minor amount glauconite.

**819-846**: Somewhat argillaceous and sparry limestone.

**846-864**: Limestone as above, frequent glauconitic fine sandstone interbeds. Moderately, occasionally well consolidated. Calcite Cemented.

## Mossheddinge-1

**580-594**: Coarse, somewhat calcareous sand, grading downwards into coarse sandstone, moderately consolidated calcite cemented . Frequent calcareous matrix. Glauconite traces.

**594-600**: Medium to fine sand, alternating with somewhat calcareous, silty, fine sandy clay. Thin interbeds of calcite cemented sandstone as above.

**600-636**: Argillaceous, fine sandy limestone. Interbeds of sandy, silty and calcareous clay. Minor glauconite.

**636-652**: Fine to medium, occasionally coarse sandstone. Moderately consolidated, occasionally well consolidated. Silica and calcite cemented. Frequent argillaceous matrix. Glauconite, detrital coal common.

**652-668**: Fine to medium, variably calcareous sandstone. Moderately consolidated. Calcite cemented. Interbedded with sandy, argillaceous, silty limestone. Coarse to very coarse sandstone. Poorly consolidated. Frequently friable. Loose sand at 657-660 m.

**668-673**: Fine sandstone. Very well consolidated, silica cemented .

**673-690**: Argillaceous, fine sandy, silty sandstone. Occasionally very hard, silica cemented. Interbeds of calcareous clay at the top.

**690-698**: Fine to medium, calcareous sandstone. Well consolidated. Calcite emented. Basal metres are coarse sand.

**698-712**: Fine sandstone as above. Interbeds of clay. Thin beds of coarse sand.

**712-715**: Coal

**715-724**: Very fine to fine, variably calcareous sandstone. Moderately, occasionally well consolidated, calcite and silica cemented. Glauconite traces.

**724-729**: Silty, calcareous clay. Interbeds of calcareous, very fine, argillaceous siltstone. Thin interbeds of sandstone as above.

**729-732**: Sandstone as above.

**732-738**: Clay and very fine sandstone as above.

**738-744**: Variably silty, sandy, somewhat argillaceous limestone. Traces of glauconite, coal.

**744-794**: Very calcareous, slightly sandy and silty clay.

**794-816**: Clay as above. Interbedded with fine occasionally medium, variably calcareous sandstone. Variably consolidated. Cemented with silica and calcite. Traces of glauconite. Occasional beds of argillaceous, silty, fine sandy limestone.

**816-818**: Coal.

**818-831**: Dominantly fine, occasionally medium to coarse sandstone. Mainly well consolidated. Thin interbeds of limestone as above. Traces of glauconite,coal.

**831-837**: Coarse, occasionally very coarse sand.

**837-846**: Dominantly fine to very fine, calcareous sandstone. Well consolidated. Cemented with calcite and silica.

**846-867**: Sandstone as above. Interbeds of slightly glauconitic silty, calcareous and argillaceous limestone. Traces of glauconite.

**867-869**: Variably fine to coarse, moderately consolidated sandstone. Cemented with calcite and silica. Traces of glauconite.

**869-871**: Very fine, silty, argillaceous sandstone.

**871-872**: Sandstone as at 867-869 m.

**872-882**: Argillaceous, silty, occasionally fine sandy limestone. Traces of glauconite.

**882-886**: Fine sandstone as above.

**886-890**: Coarse to very coarse sand.

**890-908**: Silty and very fine sandy clay. Occasionally interbedded with argillaceous limestone. Significant glauconite.

## Svedala-1

**693-717**: Medium to fine, very calcareous, argillaceous, variably glauconitic sandstone. Moderately consolidated, generally calcite cemented. Occasionally fossiliferous. Alternating with sandy, argillaceous, variably glauconitic limestone. Moderately consolidated, occasionally sparry. Minor beds of very calcareous, occasionally fine sandy clay. Frequent glauconite. Traces of organic rich clay laminae in argillaceous intervals. Basal metres variably sandy and argillaceous limestone.

## Nyhem-1

**615-755**: Very fine, calcareous, variably argillaceous sandstone. Alternating with very silty fine, calcareous sandstone. Moderately consolidated, calcite cemented. Occasional argillaceous matrix. Thin beds of clean quartzose fine sandstone. Moderately consolidated, occasionally well consolidated. calcite and silica cemented. Glauconite frequent in all three lithologies. Occasional bed with significant organic material.

**755-785**: Fine to medium, calcareous, variably argillaceous sandstone. Moderately consolidated, occasionally well consolidated. Calcite and silica cemented. Interbeds of medium, poorly sorted sand. Minor beds of argillaceous limestone. Traces of glauconite, pyrite.

**785-842**: Mainly limestone minor beds of sandstone as above.

**842-868**: Fine to medium, variably calcareous, argillaceous sandstone, moderately consolidated, frequently friable. Minor bed of medium sand. Traces of glauconite.

**868-873**: Fine sandy and silty limestone as above.

**873-922**: Medium sand and sandstone as above.

**922-945**: Fine sandy and silty limestone as above.

**945-959**: Sand and sandstone as above.

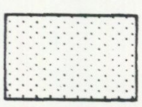
**959-995**: Fine sandy, variably argillaceous, very silty limestone. Occasionally glauconitic.

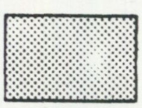
**995-1065**: Alternating limestone, sandstone and sand as in above lying intervals. The content of clay and calcareous material varies as do the content of glauconite and pyrite. Dominantly moderately consolidated. However, friable, loose sandstone, and sand are frequent.

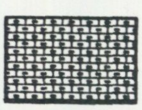
COMPOSITE LITHOLOGS

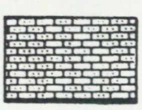


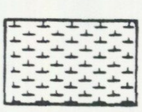
## Legend to the lithologs


Dominantly coarse-grained sandstone

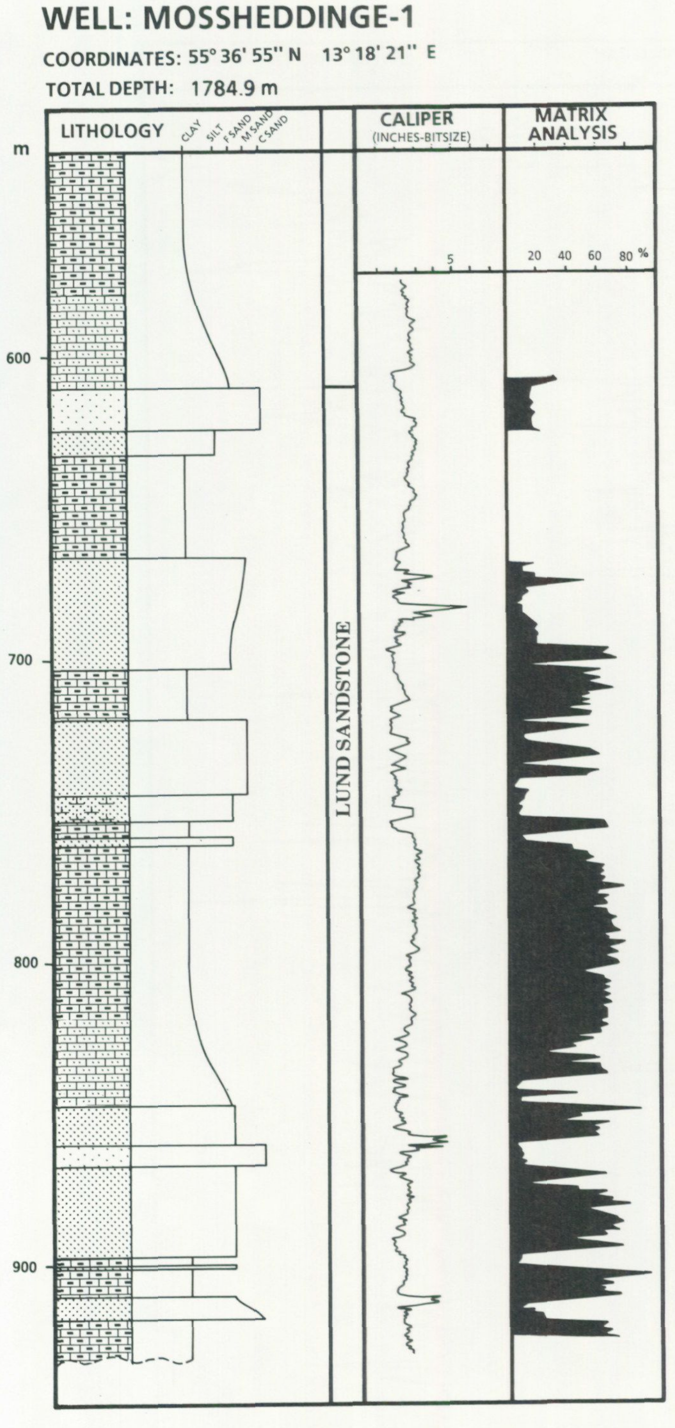

Dominantly medium- and fine-grained sandstone

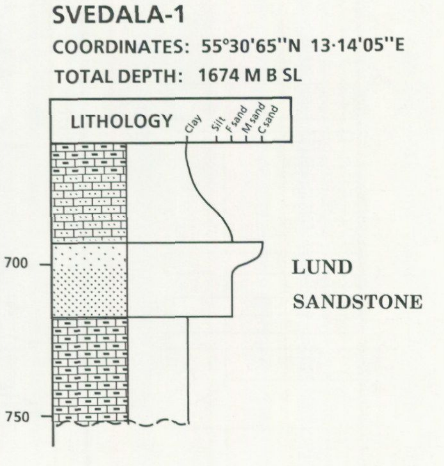

Dominantly argillaceous limestone


Dominanatly arenaceous limestone


Calcareous lithology

SP: Self potential log
GR: Gamma ray log
MSFL: Microspherically focussed log

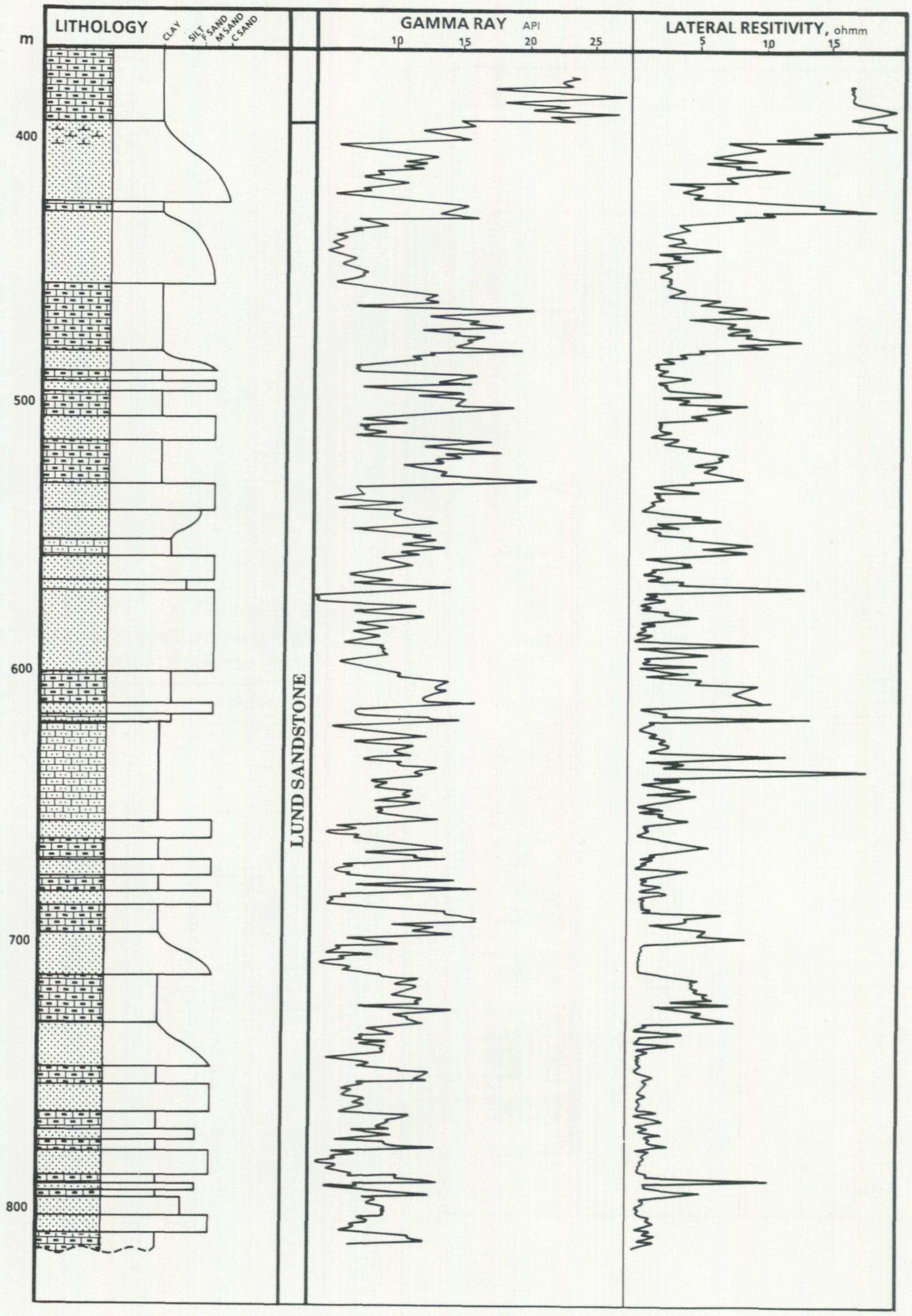

WELL: MOSSHEDDINGE-1
COORDINATES: 55° 36' 55'' N 13° 18' 21'' E
TOTAL DEPTH: 1784.9 m
LITHOLOGY
CLAY
SILT
F SAND
M SAND
C SAND
CALIPER
(INCHES-BITSIZE)
MATRIX
ANALYSIS
m
5
20 40 60 80 %
600
700
800
900
LUND SANDSTONE


SVEDALA-1
COORDINATES: 55°30'65''N 13·14'05''E
TOTAL DEPTH: 1674 M B SL
LITHOLOGY
Clay
Silt
F sand
M sand
C sand
700
750
LUND
SANDSTONE

# WELL KYRKHEDDINGE-1

Coordinates: 55° 39' 09''N 13° 16' 00'' E

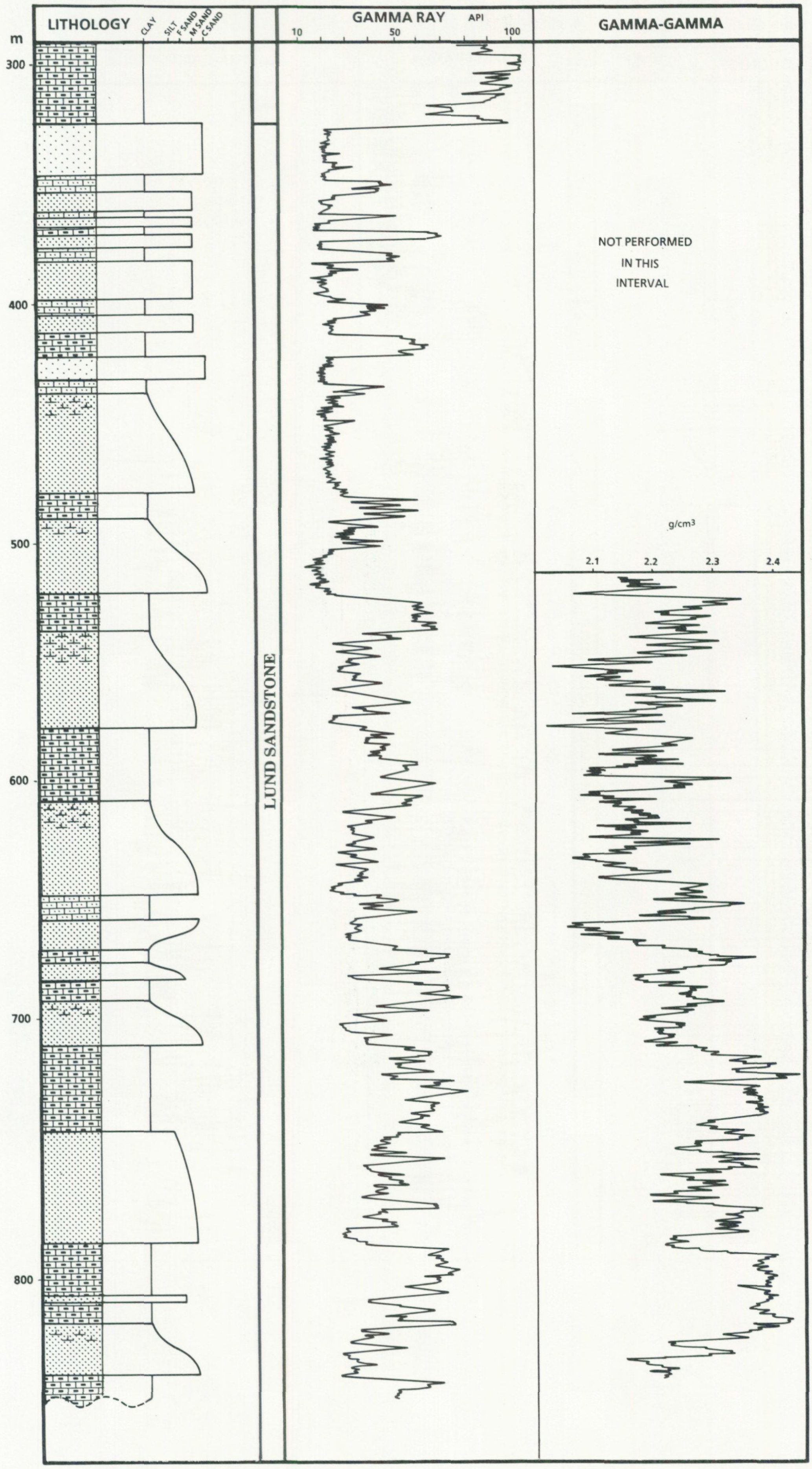
Total depth: 819.5 m



**WELL KYRKHEDDINGE-2**

Coordinates: 55° 39' 34" N 13° 15' 57" E

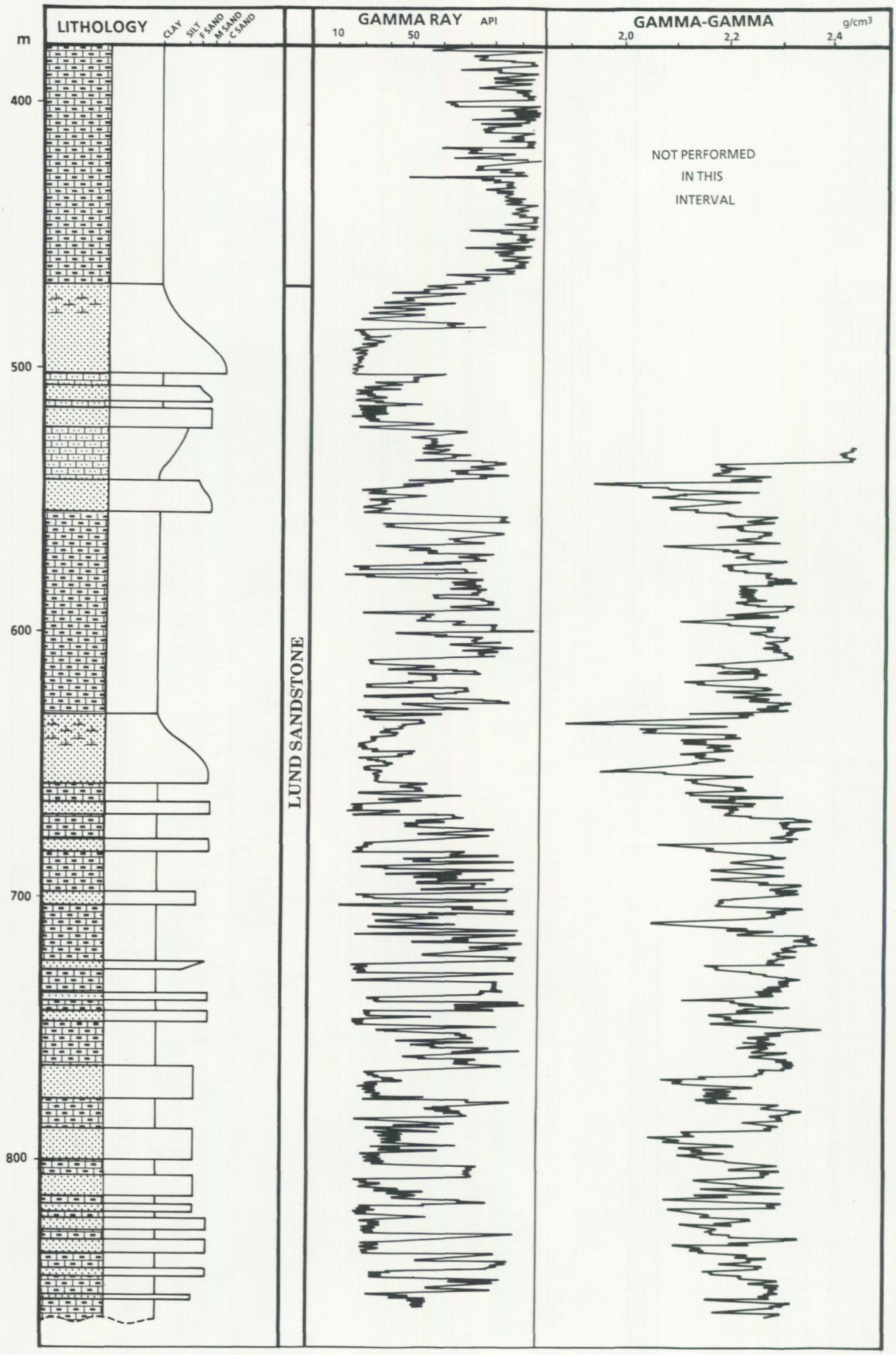
Total depth: 866.7 m

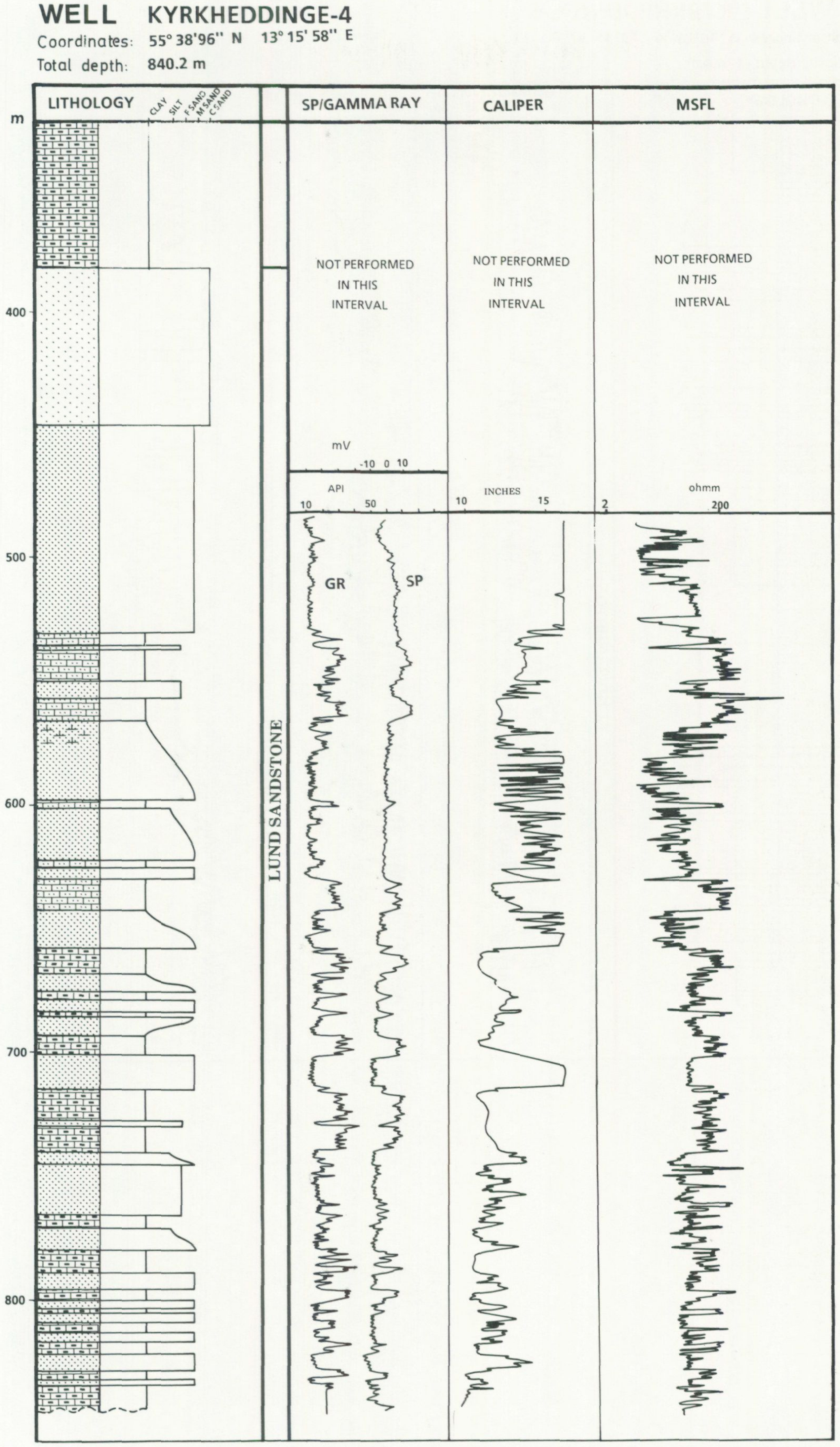


## WELL KYRKHEDDINGE-3

Coordinates: 55° 38' 34'' N 13° 15' 30'' E

Total depth: 874.2 m

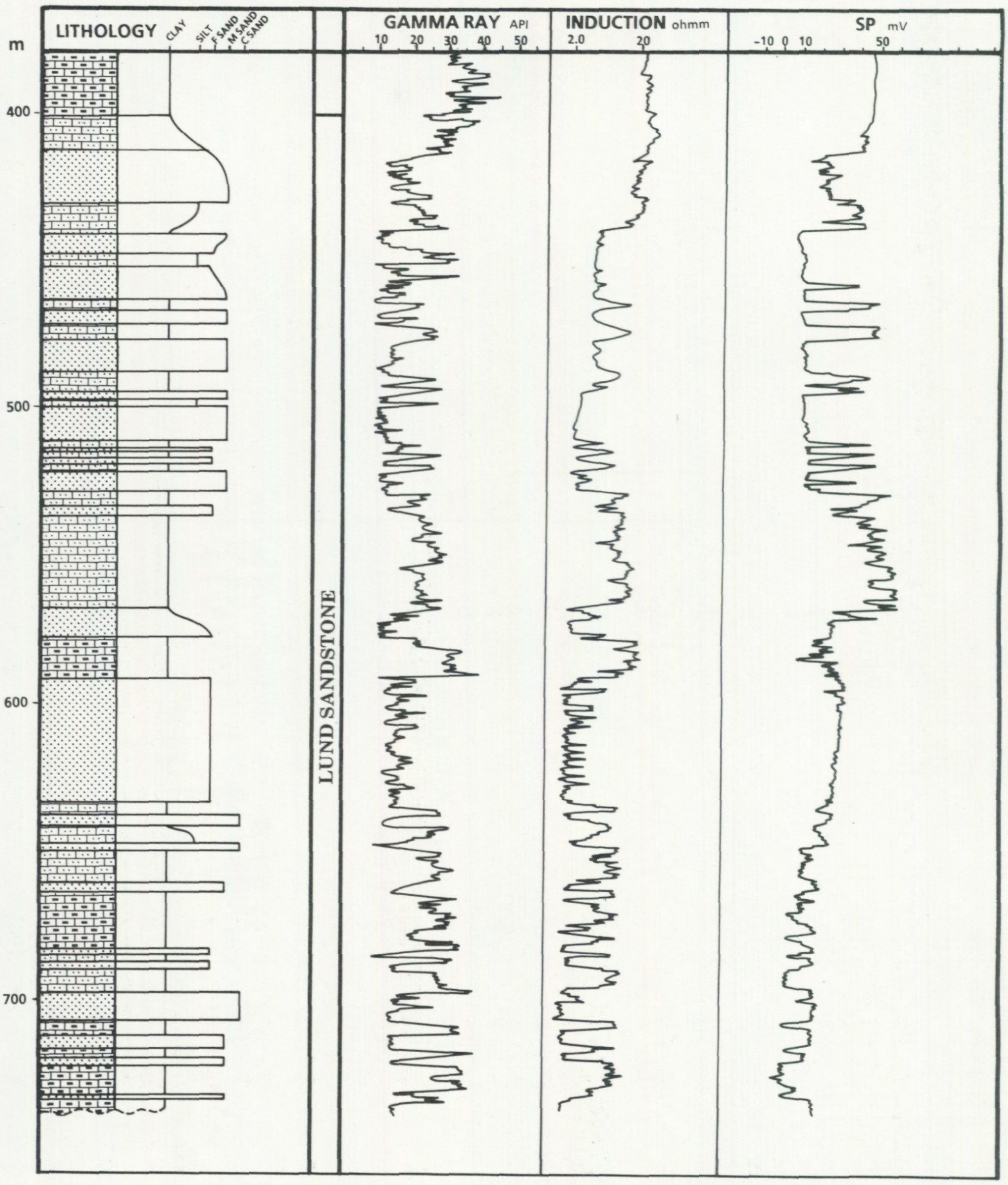



WELL KYRKHEDDINGE-4
Coordinates: 55° 38'96" N 13° 15' 58" E
Total depth: 840.2 m
LITHOLOGY
CLAY
SILT
F.SAND
M.SAND
C.SAND
SP/GAMMA RAY
CALIPER
MSFL
m
400
500
600
700
800
NOT PERFORMED
IN THIS
INTERVAL
mV
-10 0 10
API
10 50
INCHES
10 15
ohmm
2 200
GR
SP
LUND SANDSTONE

**WELL KYRKHEDDINGE-5**

Coordinates: 55° 38' 89''N 13° 15' 57''E

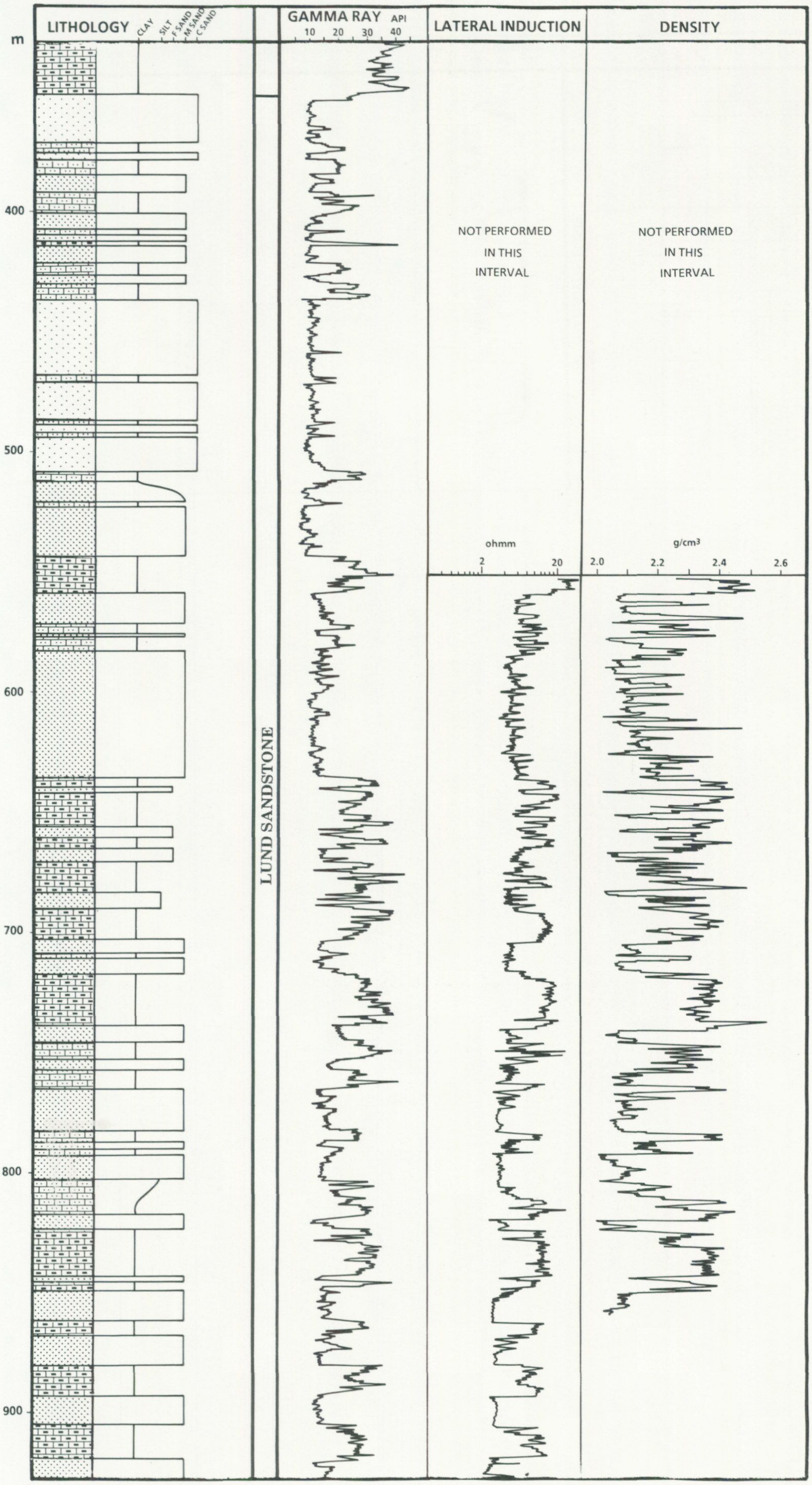
Total depth: 734.4 m



## WELL KYRKHEDDINGE-6

Coordinates: 55° 39' 38"N 13° 15' 81"E

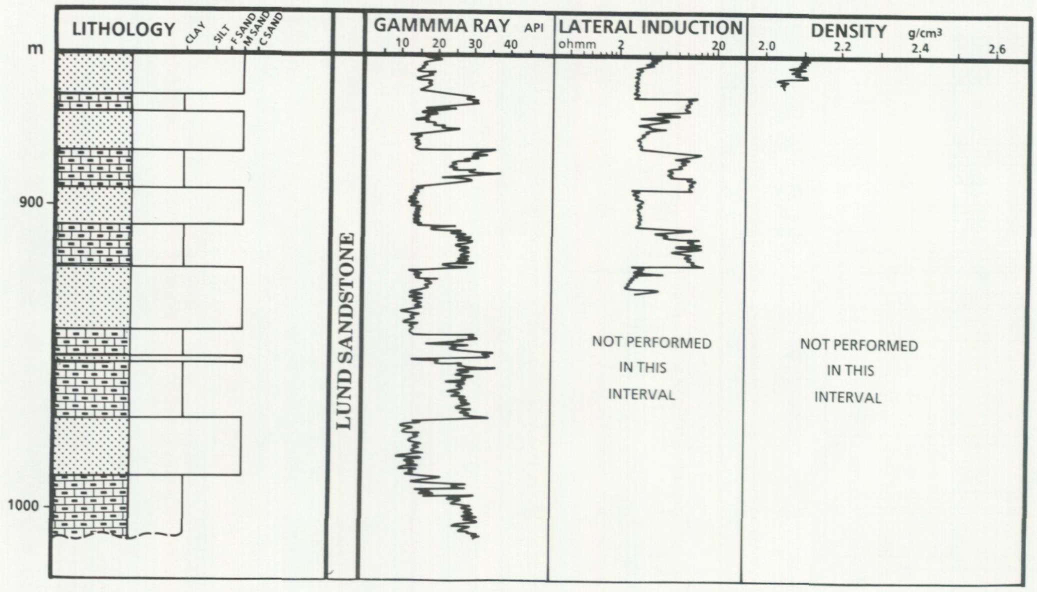
Total depth: 1009.0 m



# WELL KYRKHEDDINGE-6

Coordinates: 55° 39' 54" N 13° 15' 54" E

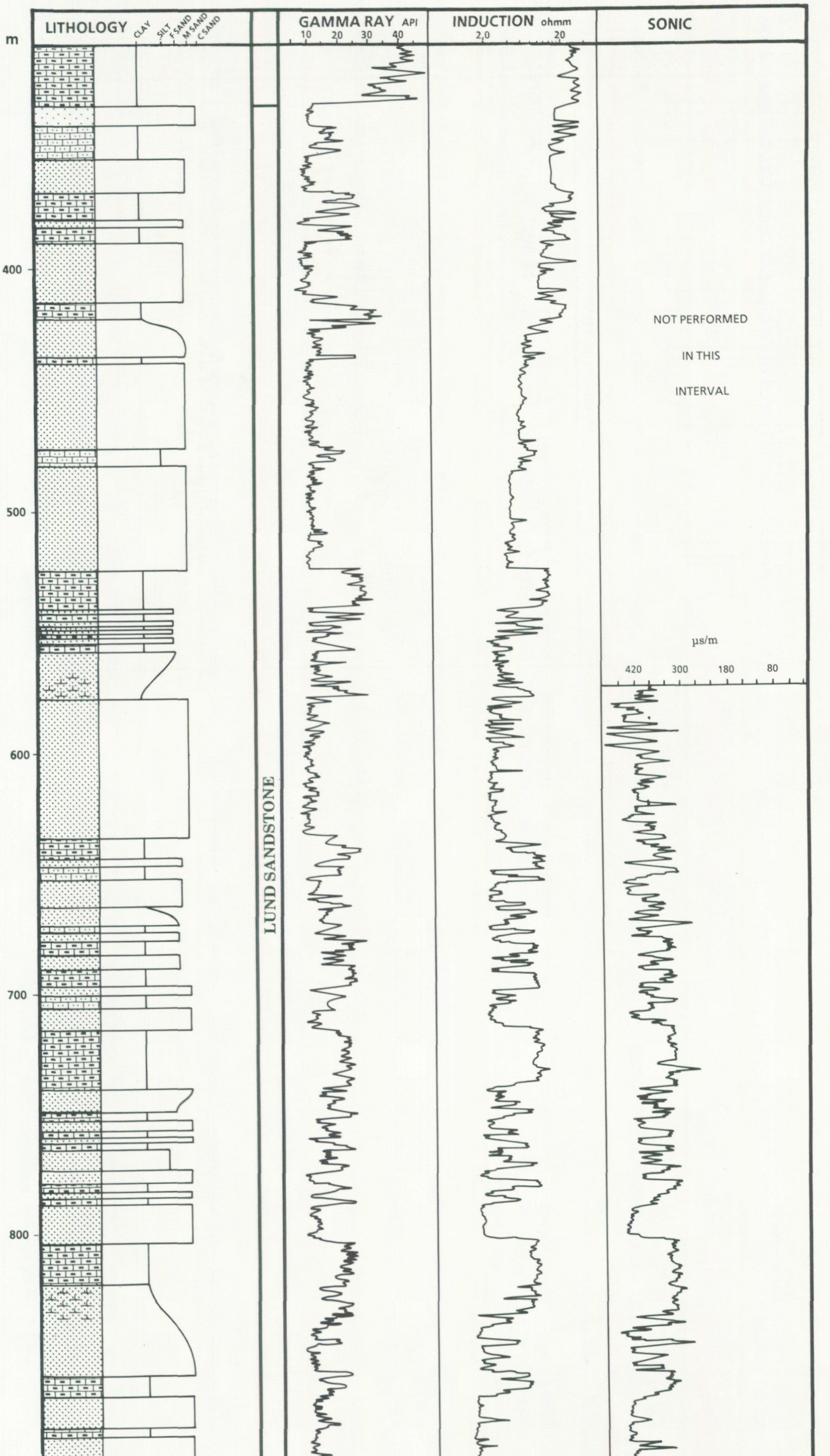
Total depth: 1009.0 m

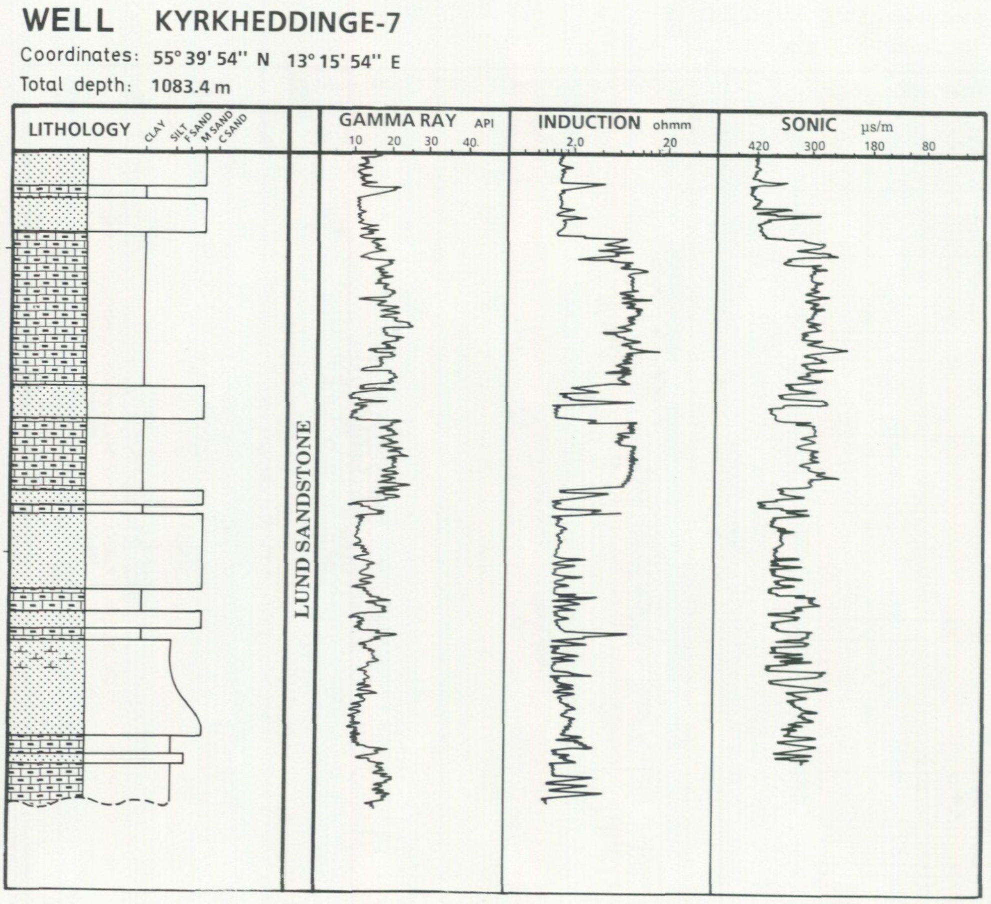


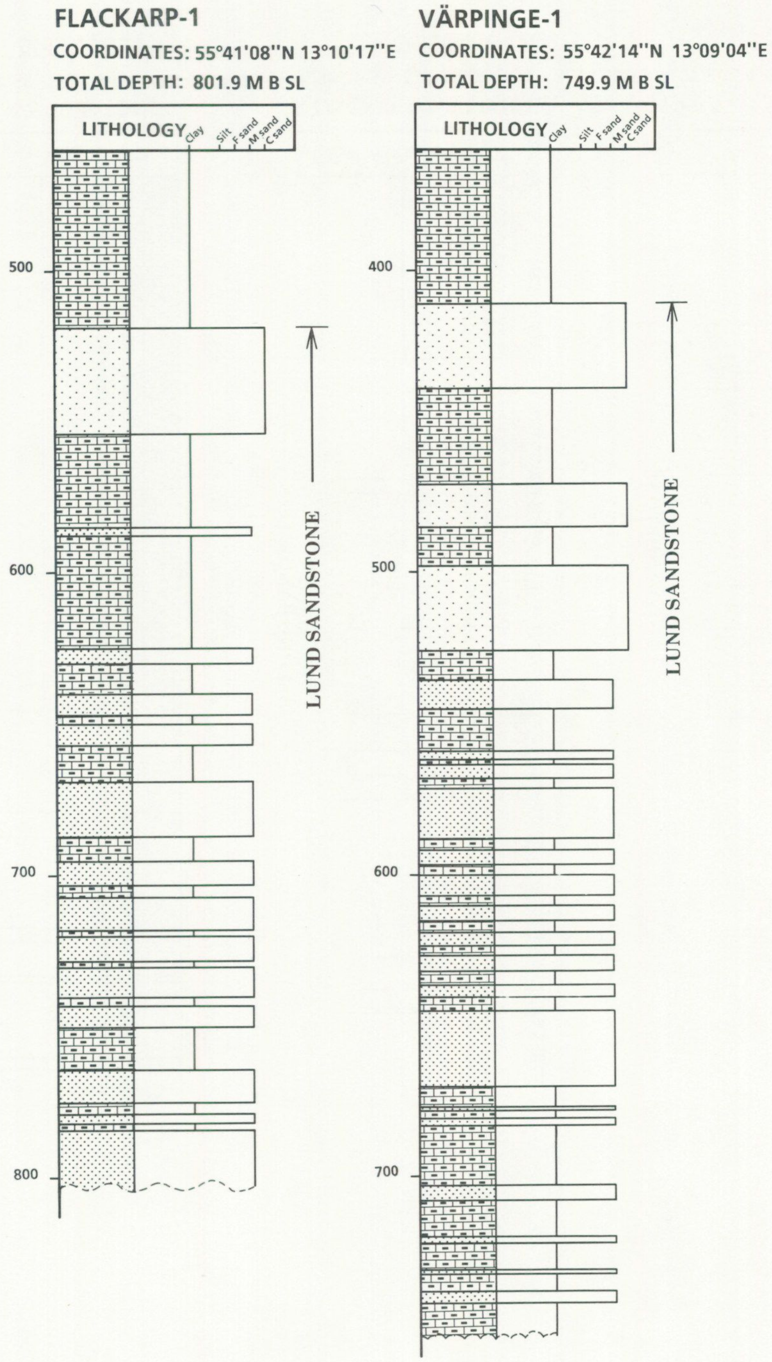
## WELL KYRKHEDDINGE-7

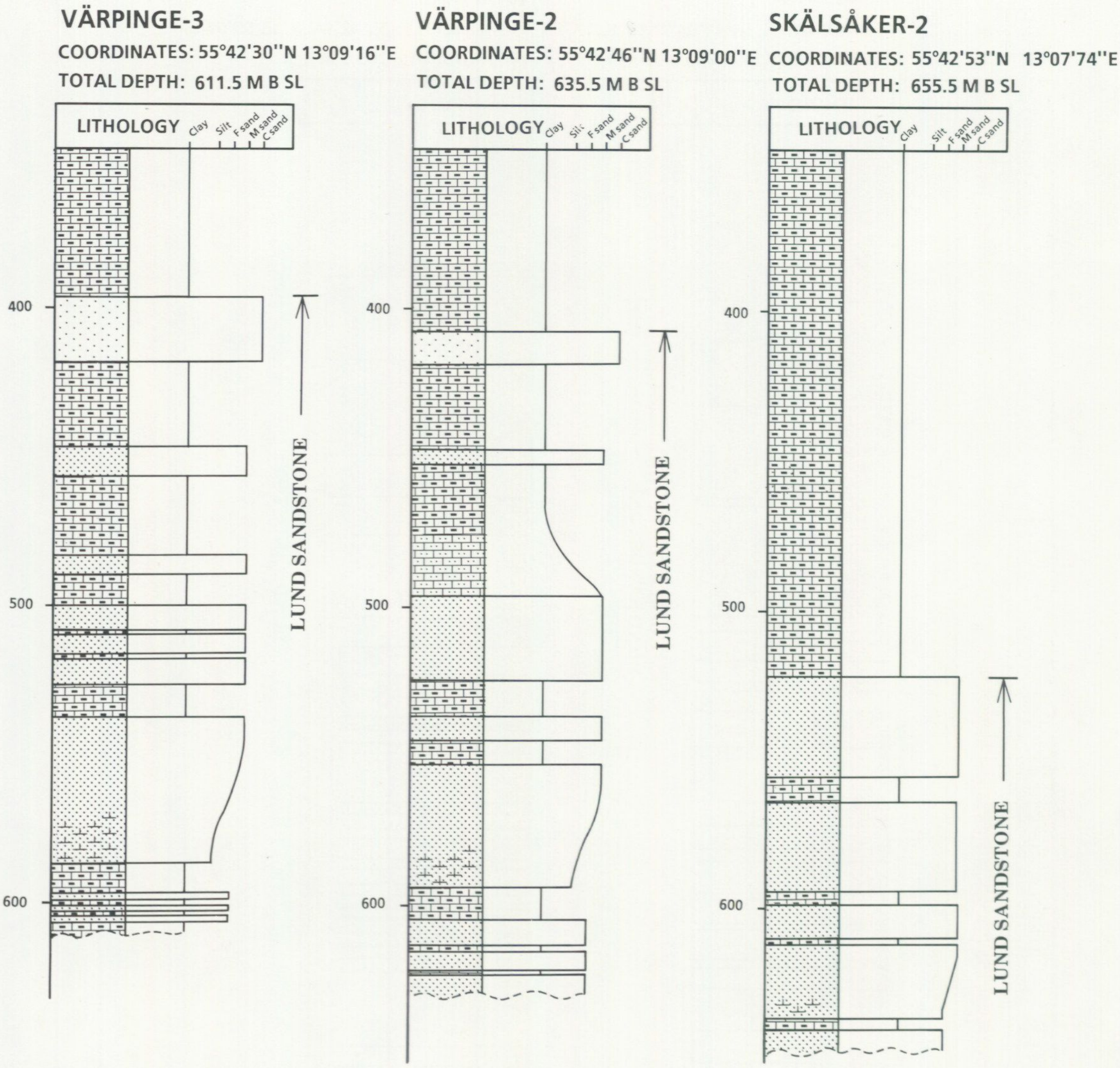
Coordinates: 55° 39' 54'' N 13° 15' 95'' E

Total depth: 1083.4 m




WELL KYRKHEDDINGE-7
Coordinates: 55° 39' 54'' N 13° 15' 54'' E
Total depth: 1083.4 m
m
LITHOLOGY
CLAY
SILT
F SAND
M SAND
C SAND
GAMMA RAY API
10 20 30 40
INDUCTION ohmm
2.0 20
SONIC µs/m
420 300 180 80
900
1000
1100
LUND SANDSTONE

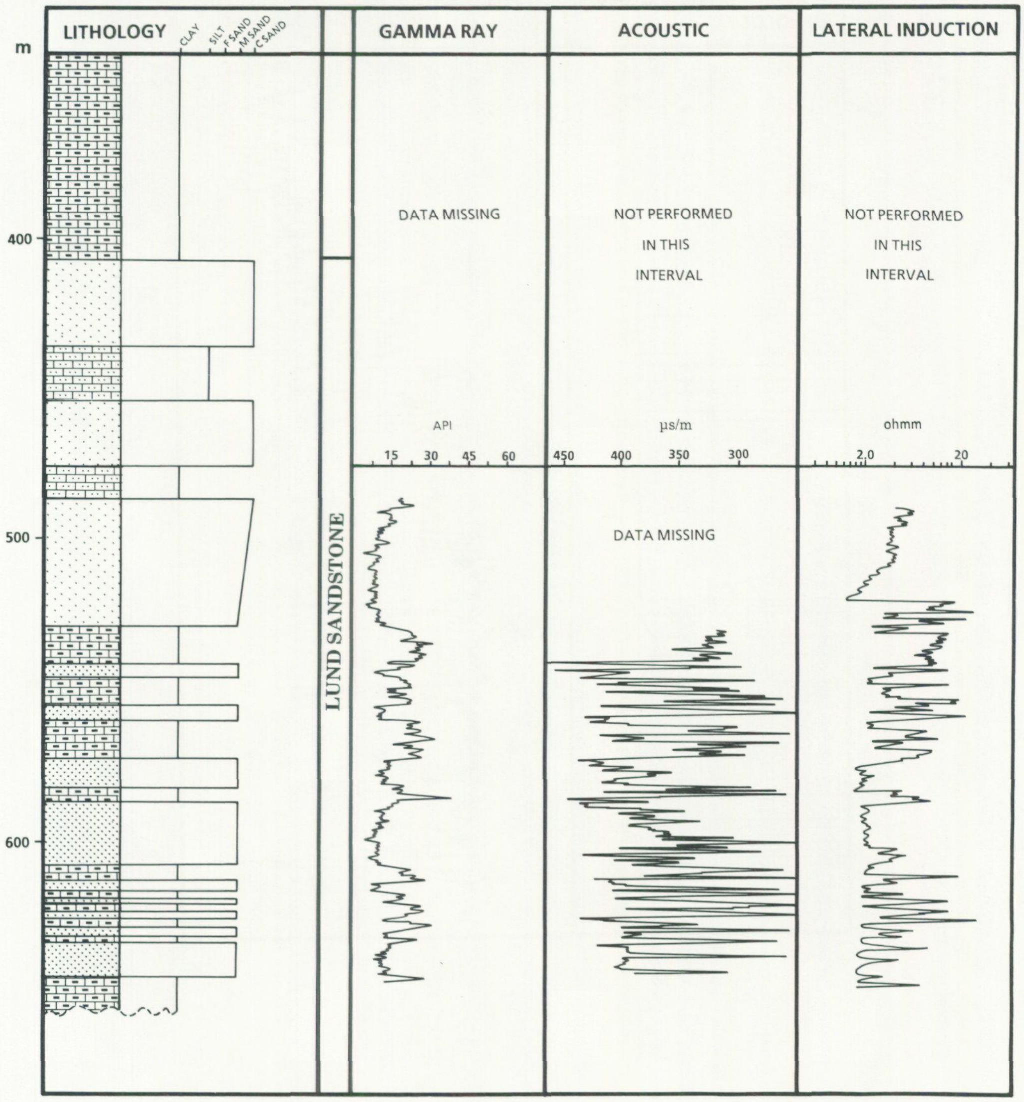

FLACKARP-1
COORDINATES: 55°41'08''N 13°10'17''E
TOTAL DEPTH: 801.9 M B SL
LITHOLOGY
Clay
Silt
F sand
M sand
C sand
500
600
700
800
LUND SANDSTONE
VÄRPINGE-1
COORDINATES: 55°42'14''N 13°09'04''E
TOTAL DEPTH: 749.9 M B SL
LITHOLOGY
Clay
Silt
F sand
M sand
C sand
400
500
600
700
LUND SANDSTONE


VÄRPINGE-3
COORDINATES: 55°42'30''N 13°09'16''E
TOTAL DEPTH: 611.5 M B SL
LITHOLOGY
Clay
Silt
F sand
M sand
C sand
400
500
600
LUND SANDSTONE
VÄRPINGE-2
COORDINATES: 55°42'46''N 13°09'00''E
TOTAL DEPTH: 635.5 M B SL
LITHOLOGY
Clay
Silt
F sand
M sand
C sand
400
500
600
LUND SANDSTONE
SKÄLSÅKER-2
COORDINATES: 55°42'53''N 13°07'74''E
TOTAL DEPTH: 655.5 M B SL
LITHOLOGY
Clay
Silt
F sand
M sand
C sand
400
500
600
LUND SANDSTONE

## WELL: VÄRPINGE-4

COORDINATES: 55° 42' 04'' N 13° 09' 33'' E

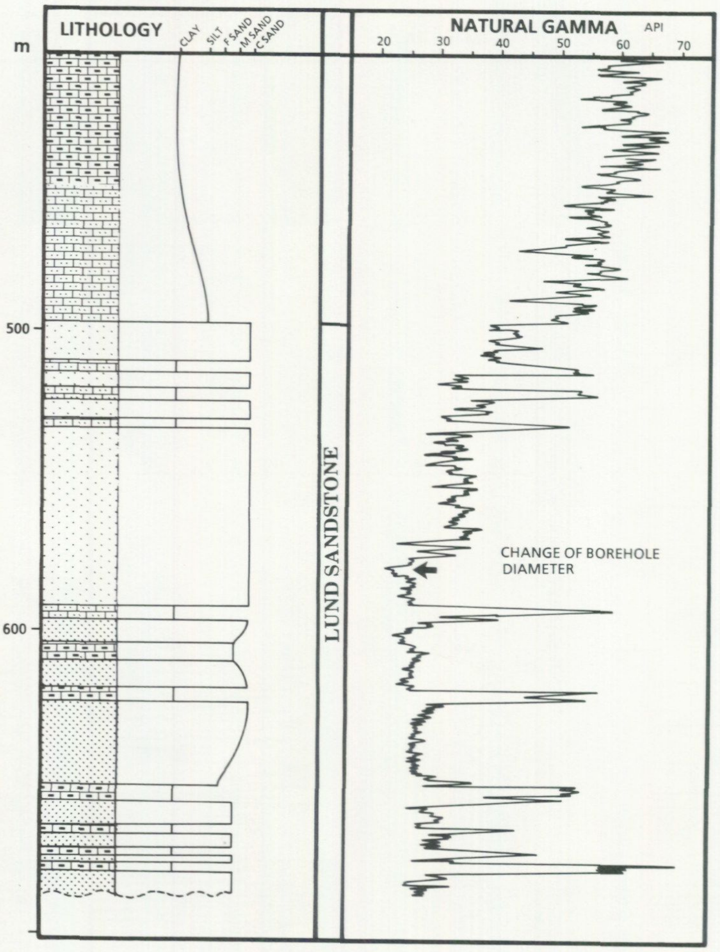
TOTAL DEPTH: 655.7 m



## WELL: SKÄLSÅKER-1

COORDINATES: 55° 42' 66'' N 13° 07' 86'' E

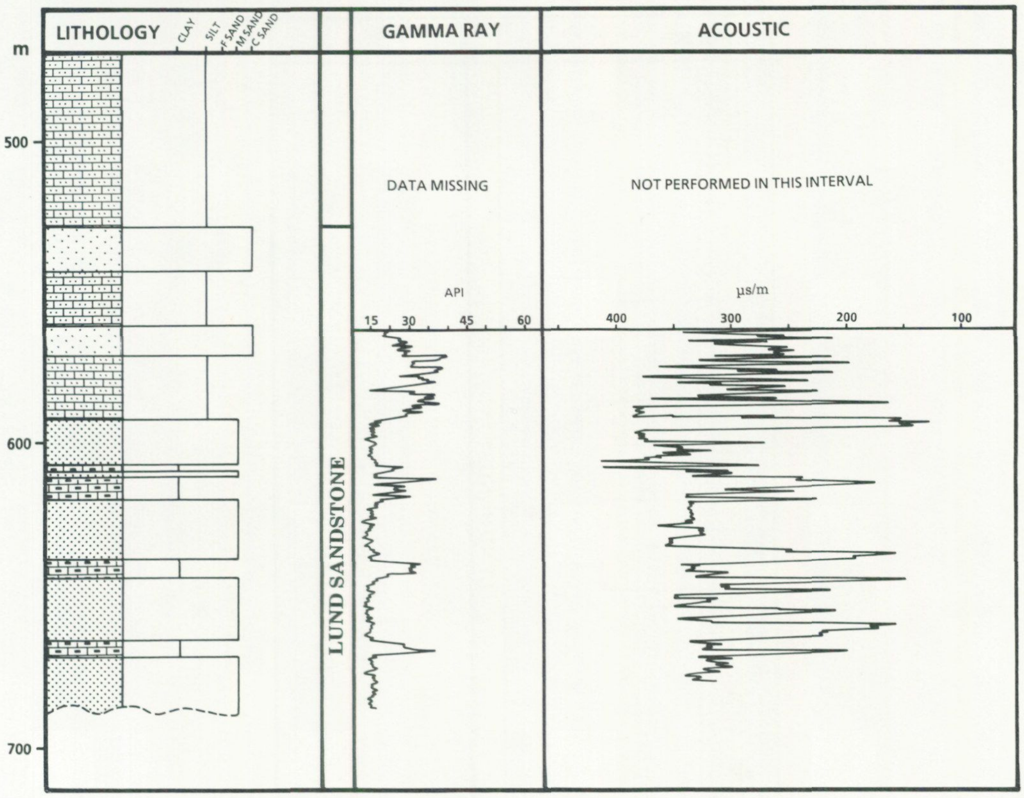
TOTAL DEPTH: 687.7 m



## WELL: HANSAGÅRDEN-1

COORDINATES: 55°42'58" N 13° 31' 15" E

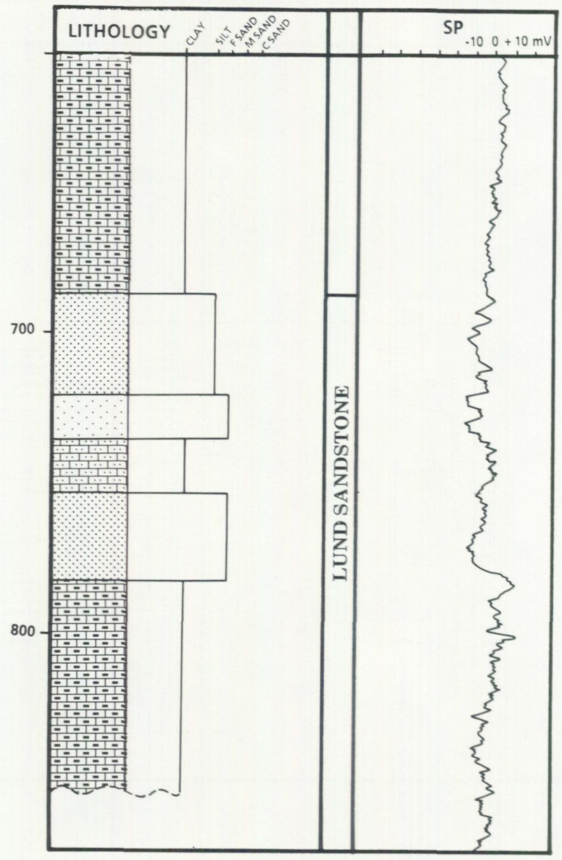
TOTAL DEPTH: 696.8 m



## WELL: NORREVÅNG-1

COORDINATES: 55° 46' 46'' N 13° 01' 28'' E

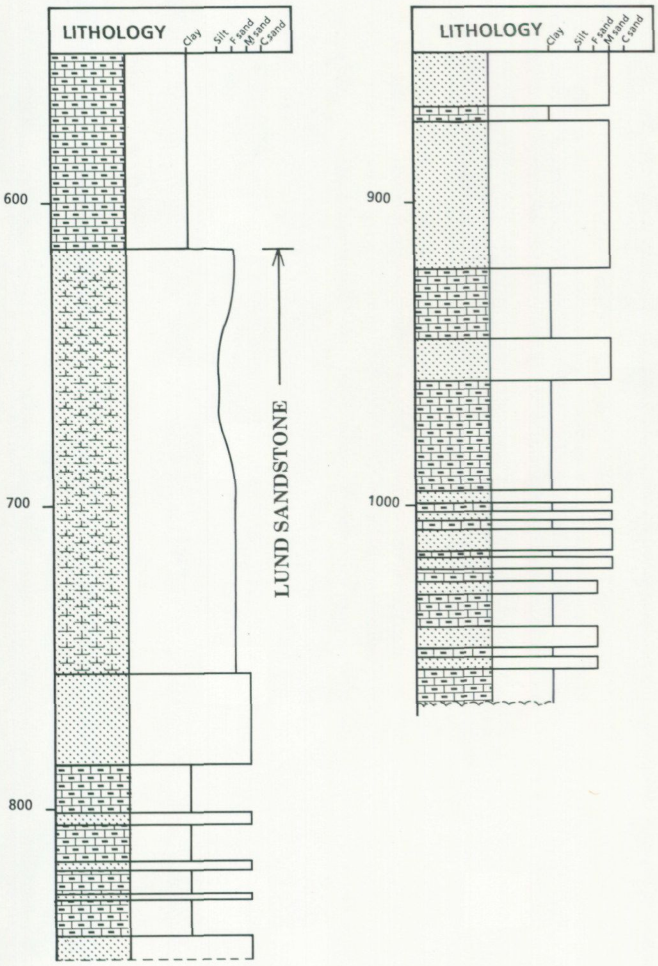
TOTAL DEPTH: 2096.8 m



**NYHEM-1**

COORDINATES: 55°43'47''N 12°51'43''E

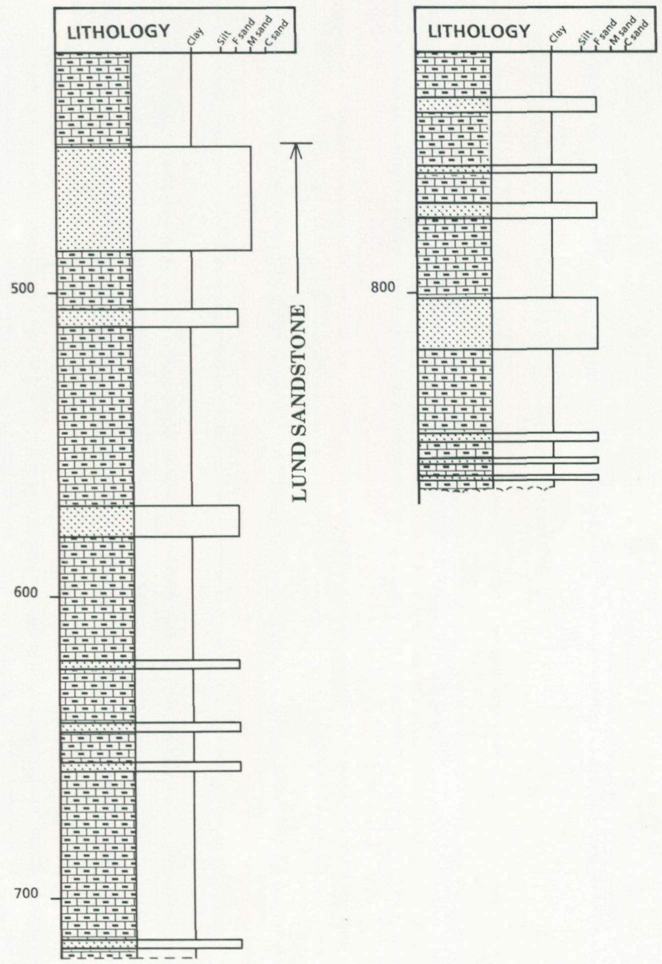
TOTAL DEPTH: 1065 M B SL




**BARSEBÄCK-1**

COORDINATES: 55°44'49''N 12°55'42''E

TOTAL DEPTH: 2254.9 M B SL



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