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MIKAEL ERLSTRÖM, DOROTHY GUY-OHLSON
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ABSTRACT

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Sediments from sections at Eriksdal, southeast Scania, of Late Jurassic-Early Cretaceous age and representing two lithological members, namely the Fyledal Clay and the Vitabäck Clays, of the Annero Formation have been investigated petrographically and biostratigraphically. The sections are characterized by more or less argillaceous lithologies with occasional sandstone interbeds. The clayey beds in the Fyledal Clay are dominated by illite and kaolinite while in the Vitabäck Clays they are mainly composed of illite, kaolinite and a mixed-layer component (smectite-illite). Fe-oxyhydroxides and siderite constitute important minerals in the sandstone interbeds, especially in the Vitabäck Clays. Organic rich beds, rootlet horizons and reddish layers together with enrichment of trace elements indicate periods of sub-aerial deposition and pedogenic processes. Infill sequences, washover fans, carbonate nodular horizons, calcretes together with faunal and floral elements indicate deposition within marginal freshwater-brackish-marine environments such as coastal plains, lakes and lagoons. The fossil content includes a variety of faunal and floral genera representing molluscs, ostracodes and palynomorphs whose stratigraphical ranges have confirmed and narrowed the age determination of the investigated sediments. In the section of the Vitabäck Clays the palynomorphs, consisting mainly of pollen grains and spores, provide the most complete coverage of the transition from the latest Jurassic to the earliest Cretaceous.

Introduction

On the Swedish mainland sedimentary rocks of Late Jurassic-Early Cretaceous age are known only from Scania. As the strata are mainly covered by younger rocks including Quaternary deposits our knowledge is somewhat restricted. Outcrops of this age, however, though few, are to be found in minor areas to the southeast, at Eriksdal in the Vomb Trough. Late Jurassic – Early Cretaceous sediments lying directly beneath the Quaternary deposits are to be found in the Ängelholm Trough and at the eastern margin of the Danish Embayment. Borehole sequences show that deposits of this age are also present beneath the Cretaceous to Palaeogene cover in the Danish Embayment, the Vomb Trough and off-shore in the Hanö Bay (Guy-Ohlson & Norling, 1988).

Most of our present knowledge of rocks of this age in Sweden is based on their fossil content, e.g. palynomorphs (Guy-Ohlson 1985; Guy-Ohlson & Norling 1988), foraminifers (Norling 1970, 1972; Guy-Ohlson & Norling 1988) and ostracodes (Oertli et al. 1961; Christensen 1968).

Nilsson (1953) described the geological outline of the Eriksdal area from a lithological and stratigraphical point of view. Unfortunately Nilsson (who later changed his name to Stenesträm) died before he published his results. Later, Christensen (1968) described the ostracode material collected by Nilsson.

Some comments upon the molluscan fauna in the Vitabäck Clays at Eriksdal were made by Hägg (1940). He suspected a Late Jurassic – Early Cretaceous age. Later Ekström (1985) described some macrofossils in material from localities sampled and described by Nilsson (1953).

STAGE	Area / Litho-stratigraphy	ÄNGELHOLM TROUGH	LANDSKRONA AREA	VOMB TROUGH Assmåsa	VOMB TROUGH Eriksdal
BERR / PORT	VITABÄCK CLAYS	Dark grey, black and brown silty clays 12m	Grey, green and brown silty clays >5m	Dark grey, soft claystones and clays, partly sandy 18m	Alternating beds of brown, black and green/grey clay, siltstone and fine grained sandstone >34m
		Dark grey, partly sandy and silty clays and coal 19m			
KIMMERIDGIAN	NYTORP SAND	Light brown, white and greenish grey sandstones Partly argillaceous and ferruginous and with calcareous horizons 26m	Whitish, uncemented silt and sand, partly rich in coal grains 20m	Sand 5m	Covered 20m
			Light, brown siltstone 2m		
KIMMERIDGIAN / OXFORDIAN	FYLEDAL CLAY	Dark green, light green, brown and greenish blue clays and claystones 34m	Brownish and greenish partly silty clays with conglomerates and thin layers of marls and limestones 10m	Grey and green soft, partly silty, claystones and coal 24m	Green and black clay interbedded with thin beds of of partly ferruginous sandstone. Calcareous horizons and rootlet beds 140m?
			Greasy, blue, brown and green claystones with thin layers of clay and brown ferruginous claystones 22m		

Fig. 1. Summarised data concerning lithology and thickness of the Fyledal Clay, Nytorp Sand and Vitabäck Clays in different parts of Scania.

Geological setting

The Upper Jurassic sediments of Sweden lie within the border zone between two geological regimes, i.e. between the East European Platform and the NW European area of subsidence (including the North Sea and adjacent land masses).

Though the Upper Jurassic sediments of Scania were originally mainly deposited in one and the same depression at the margin of the Fennoscandian Shield, they are at present preserved only in several down-faulted blocks (Guy-Ohlson & Norling 1988). Parts of the original depression continued to subside during the Cretaceous, but in the Late Santonian/Campanian an inversion process commenced and continued during the Cenozoic as a consequence of compressional deformation (Norling & Bergström 1987). Areas which had been subjected to transgression became land and previously deeply submerged deposits were eroded. The deposits have been differentially eroded in connection with Kimmerian block-faulting and Late Cretaceous–Cenozoic movements.

The Upper Jurassic of Scania has been subdivided into different lithostratigraphical units which are regionally correlative over fairly large areas (Guy-Ohlson & Norling 1988). Further lithological aspects are to be found in Norling (1972, 1981). A table briefly summarising the pertinent data for the lithostratigraphical units in different parts of Scania is given in Fig. 1.

The Upper Jurassic of NW Scania is preserved in a down-faulted area known as the Ängelholm Trough situated at the northeast margin of an inverted tectonic block which traverses Scania from NW to SE (Guy-Ohlson & Norling 1988, Figs 2 & 3). Further information concerning the geological setting of the Ängelholm Trough and the lithostratigraphy of the units represented in this area is given in detail in Guy-Ohlson & Norling 1988, pp. 8–10.

In SE Scania in the Fyle Valley of the Vomb Trough and further towards the west, in the flexure-fault zone forming the boundary between the Fennoscandian Border Zone and the Danish Embayment, Upper Jurassic strata occur beneath the Quaternary cover. Eriksdal is located in the Vomb Trough, which is a narrow graben, approximately 80 km in length and with a width ranging from 7 km in the northern part to 11 km in the southern part. Rather complex tectonic evolution is known for the area. Norling in Bergström & Norling (1986, pp. 5–12) has given a comprehensive geological framework for Eriksdal and the adjacent Kurremölla Valley and explained the tectonic evolution in detail. As he has also made adequate reference to previous sedimentological work of this area by Kock (1979), Rolle et al. (1979) and Koch & Surlyk (1986) it is felt that it would be superfluous to repeat the same information here. The present study also encompasses the Vitabäck Clays (Figs 2A & 2B).

A generalised palaeogeographic setting in NW Europe and its development from Kimmeridgian to Valanginian time, resulting partly from work on the International Geological Correlation Programme (IGCP) Project Accession No. 86 – South-west border of the East European platform (familiarly known as Project Tornquist) is schematically illustrated and presented in Fig. 3.

Material

The more or less tilted and overthrusted strata at Eriksdal have been sampled at two separate sections. The Fyledal Clay section is located in the southwestern vicinity of the Fyleverken Sand Pit (Fig. 2A) within an area where Fyleverken Mineral AB quarries the clay for ceramics. The Vitabäck Clays section is located approximately 250 m WNW of the cross-roads between Eriksdal and Rödmölla (Fyleverken Mineral AB) (Fig. 2A).

THE FYLEDAL CLAY

The Fyledal section is approximately 75 m long. Slightly overthrusted strata strike on average N40°W and dip 80°NE. The exposed strata represent a true thickness of 55 m. The section is composed mainly of alternating greenish and greyish black, more or less argillaceous beds with thicknesses between 0.5 and 2.0 m. A 20 m thick bed in the middle part of the section separates the basal part from the upper, slightly heterogeneous part (Fig. 4). In the basal part there is a 1.0 m thick sand bed which wedges out laterally. Two nodular limestone layers are found in the uppermost part of the section. Due to the dominantly argillaceous and water saturated lithology sedimentary structures are generally absent or obliterated by the clay fabric. A few rootlets, however, occur in the lower part of the section. The best developed root-horizon is located at the boundary between the Glass Sand and the Fyledal Clay. Up to 30 cm long roots penetrate into the Glass Sand.

A total of 25 samples were collected from different beds in the Fyledal section.

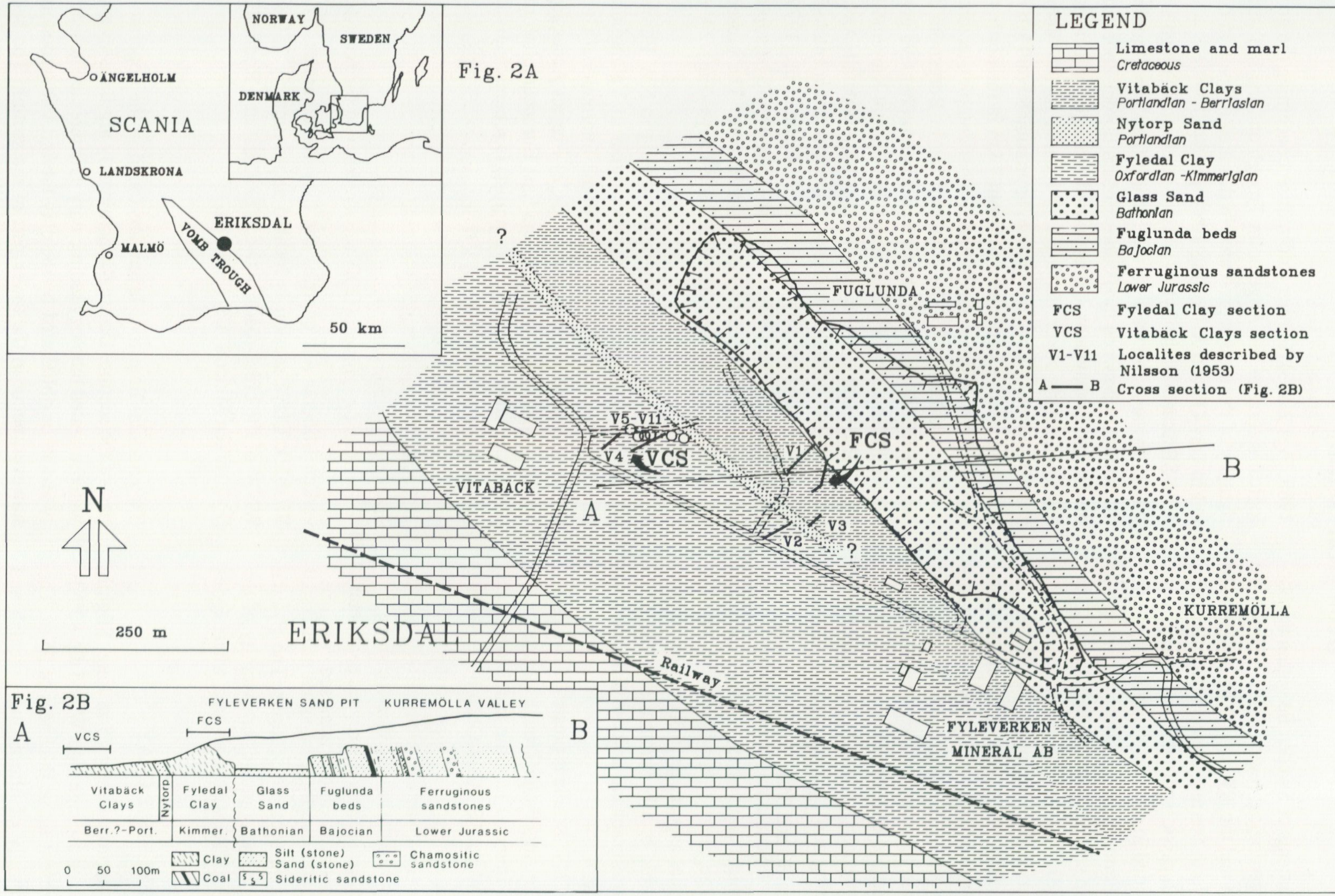


Fig. 2. A: Location map of the Eriksdal area with marked sections presented in this study and older pits and sections (Nilsson, 1953). B: Schematic cross section of the sedimentary sequence at Kurremölla – Fyleverken Sand Pit – Vitabäck. (Modified after Oertli, Brotzen & Bartenstein 1961).

THE VITABÄCK CLAYS

The Vitabäck section is characterized by alternating, differently coloured and more or less argillaceous beds. There is, however, a higher frequency of silty and sandy beds than in the Fyledal Clay section. The section was opened in 1989 by the use of an excavator and assistance from Fyleverken Mineral AB. The Quaternary cover was removed and the underlying Vitabäck strata exposed at the bottom of a 2–3 m deep and 50 m long ditch. A fossiliferous (coquina) bed in the northeastern basal part of the section is used as a reference bed. The beds in the section are between 0.5 and 2 m thick and strike N40°W. The dip varies depending on how affected the beds are by superficial distortion of the Vitabäck Clays, immediately beneath the Quaternary deposits, due to the overburden pressure in the area. Thick Quaternary deposits to the east result in a pressure gradient on the water saturated Vitabäck Clays which have been sheared downslope towards the west. It is therefore somewhat difficult to calculate true bed thicknesses. Estimations have resulted in a true thickness between 30 and 35 m for the exposed section in the ditch.

The section was described and a total of 36 beds were sampled before the ditch was closed again the same day. Thus it was not possible to investigate the section more thoroughly with regard to sedimentary structures and fossils.

Petrography

METHODS

The following analytical methods and techniques were applied on the sampled sections. The two sections were at first investigated separately which has resulted in the slight mismatching of analytical techniques and analysed parameters. The Fyledal section is less completely analysed compared with the Vitabäck section, especially in its middle part. This part contains intervals where samples were not taken due to Quaternary debris covering the section. There is also an interval in the Vitabäck section where samples are missing because the open ditch collapsed.

The analyses performed were:

- Grain-size
- Organic content and LOI
- X-ray powder diffraction
- SEM (scanning electron microscopy)
- Bulk chemical composition
- CEC (cation exchange capacity)
- TG (thermal gravity).

The most important analyses for this investigation have been the bulk chemical composition and the XRD-analysis. The other analyses have been used for complementary data on certain beds and lithologies.

Grain-size analysis

The grain-size analysis on samples from the Vitabäck section was focused on a quantification of the <2 µm and >63 µm fractions. Between 20 and 35 g of dried (105°C) bulk material from each sampled bed was gently crushed in a mortar. The crushed material was dispersed in distilled water with added sodium-pyrophosphate (dispergent). The suspension was stirred and agitated until all aggregates were dispersed. A standard aerometer measurement was thereafter performed, based on Stoke's law on settlement of particles out of a suspension. After this measurement the suspension was washed through a 63 µm sieve. The fraction >63 µm was dried, weighed and investigated with reference to the mineral composition. The sand beds were analysed by dry sieving through the following set of sieves: 2.0, 1.0, 0.5, 0.25, 0.125 and 0.063 mm.

The samples from the Fyledal section were analysed in the same way as the Vitabäck material except for the fact that they were wet-sieved through the following sieves: 0.25, 0.125 and 0.063 mm.

Organic content and loss on ignition (LOI)

3.0 g of each sample from the Vitabäck section was gently crushed in a mortar and mixed with 20 ml $K_2Cr_2O_7$, 40 ml of concentrated sulphuric acid and 200 ml of distilled water. The solution was agitated and left undisturbed for 24 hrs. A few ml of solution was analysed by a spectrophotometer (625 nm). The absorbance (%) reading was related to the amount of organic carbon in the sample.

The loss on ignition (LOI) was determined for both the Vitabäck and Fyledal sections. On average 50 g of each sample was dried at 105°C to remove absorbed water. The samples were thereafter heated for two hours at 950°C. The weight loss was subsequently determined.

X-ray powder diffraction analysis

The characteristics of the clay mineral composition were mainly investigated by the use of X-ray diffraction techniques. The same technique was applied on samples from both sections. The <2 µm fraction was separated from the bulk sample. Approximately 50 g were dispersed in distilled water. The suspension was centrifuged and the supernatant with particles <2 µm was poured into a vacuum filtering equipment. The applied vacuum forced the suspension through a membrane filter with a pore-size of 0.47 µm. The clay particles became orientated with their basal surfaces

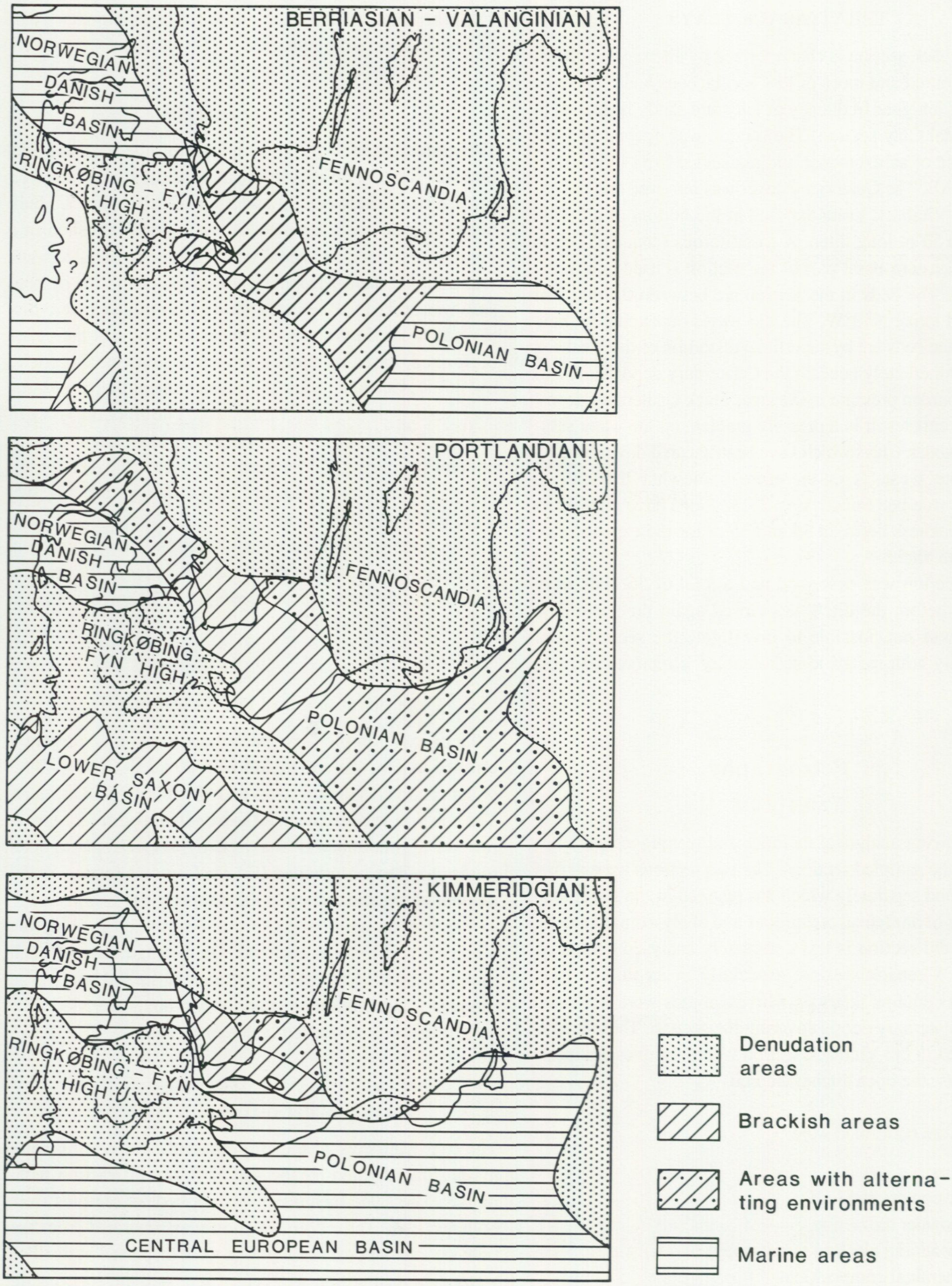


Fig. 3. Schematic illustration of the palaeogeographical setting in NW Europe during Kimmeridgian–Valanginian times. (Partly based on the lithological–palaeogeographical maps in Jubitz et al. 1988).

parallel to the filter surface. The clay cake thus produced was mounted on a glass slide and air dried. The technique has among others been presented by Drever (1973). The prepared samples were investigated over the 3–40° 2θ range with an angle speed of 1°/min on a Phillips PW 1710 diffractometer and CuKα-radiation. Ethylene glycol treated, HCl-treated, K^+-saturated and heated (450°C) mounts were analysed so as to get supplementary information about the physical characteristics. A semiquantitative estimation of the relative amounts of the clay minerals was performed according to a technique presented by Reynolds (1985). Pyrophyllite (10% by weight) was added and mixed as an internal standard with the <2 µm fraction. The intensity of the pyrophyllite 002-peak was compared with the intensities of the kaolinite 002-peak, illite (10-Å minerals) 003-peak and the 005 peak of smectite (EG-treated sample). A relative estimation of the quantities was also performed by comparison with computer generated X-ray diffractograms of known mixtures and compositions (computer programme NEWMOD copyright Reynolds 1985).

Scanning electron microscopy

This investigation was focused on a characterisation of the clay mineral microstructure and the distinction between authigenic and detrital components. A total of 15 samples from the main lithologies were investigated, mainly from the Vitabäck section.

A piece of bulk sample (2–5 g) was instant frozen with liquid nitrogen, subsequently freeze dried and thereafter broken to open the fabric. The mounted and gold–platinum coated specimens were then investigated with a JEOL-SEM equipment. Light microscopy and SEM back-scatter techniques were used to distinguish and characterize the mineral composition of the sandstones.

Geochemical analysis

A multicomponent inductive coupled plasma atom adsorption spectrometer (ICP-AES) analysis was conducted on all bulk samples from the Vitabäck section. Some samples were also analysed in the <2 µm and <0.6 µm fractions as to correlate the results of the XRD-investigation with the chemical composition.

A total of 29 elements were analysed by ICP-AES including main components (SiO_2, Al_2O_3, Fe_2O_3, K_2O, Na_2O, MnO, MgO, CaO, P_2O_5 and TiO_2) and trace elements (Ba, Be, Co, Cr, Cu, La, Mo, Nb, Ni, Pb, Sc, Sn, Sr, V, W, Y, Yb, Zn and Zr).

The bulk chemical composition of the samples from the Fyledal section was determined by X-ray fluorescence (XRF). Dried (105°C) samples were crushed and melted together with lithium-tetra-borate. Two grams of each sample were thereafter homogenized together with a cellulose and resin mixture. A compacted briquette was prepared and analysed with a Rigaku spectrometer. Analyses of the trace elements were only performed on pre-dried samples. The intensity readings were thereafter evaluated and a computer aided quantification performed. Na_2O was determined by atom adsorption on melted material.

Cation exchange capacity (CEC) and thermal gravity (TG)

The cation exchange capacity was determined by Sr^{2+} saturation of 3 samples from the Vitabäck section. This cation is chosen as it is not present in any significant amount in the natural sample. One gram of the <2 µm clay sample fraction was saturated with a 0.5 M $SrCl_2$-solution and gently agitated for 24 hrs. After centrifugation the excess salt solution was decanted and the treatment was repeated to ensure complete exchange of the exchangable cations. Finally the clay was washed free of excess salt by centrifuging with six 25 ml portions of alcohol. The amount of adsorbed Sr-ions was analysed and the CEC calculated as milliequivalents per 100 g (meq/100 g).

The thermoanalytical investigation (TG) was performed since it is an important complementary method in the qualitative and quantitative analysis of clay mixtures and associated Fe-oxyhydroxides. Ten mg of sample (<2 µm fraction) from ten samples representing three different lithologies in the Vitabäck section were dried (60°C), crushed and placed in the furnace of a thermogravimetric equipment (Netzsch simultaneous thermal analyzer STA 409). The mass change was monitored as a function of time and a differential thermogravimetric (DTG) curve was established.

RESULTS

The Fyledal Clay

Occurrence and field characteristics

The described section is located within the basal 55 m of the Fyledal Clay (Fig. 2B). The contact towards the underlying Glass Sand, composed of clean quartz sand with some minor amount of white kaolinite in the matrix, is located in the SW border of the Fyleverken sand pit. The section does not reach into the overlying Nytorp Sand. It is estimated, according to data of Nilsson (1953), that the gap is approximately 100 m between the basal part of the Nytorp Sand and the uppermost part of the section.

The investigated section together with a few scattered outcrops (localities V1 and V5 of Nilsson 1953) in the vicinity are composed of beds of variable thicknesses, most

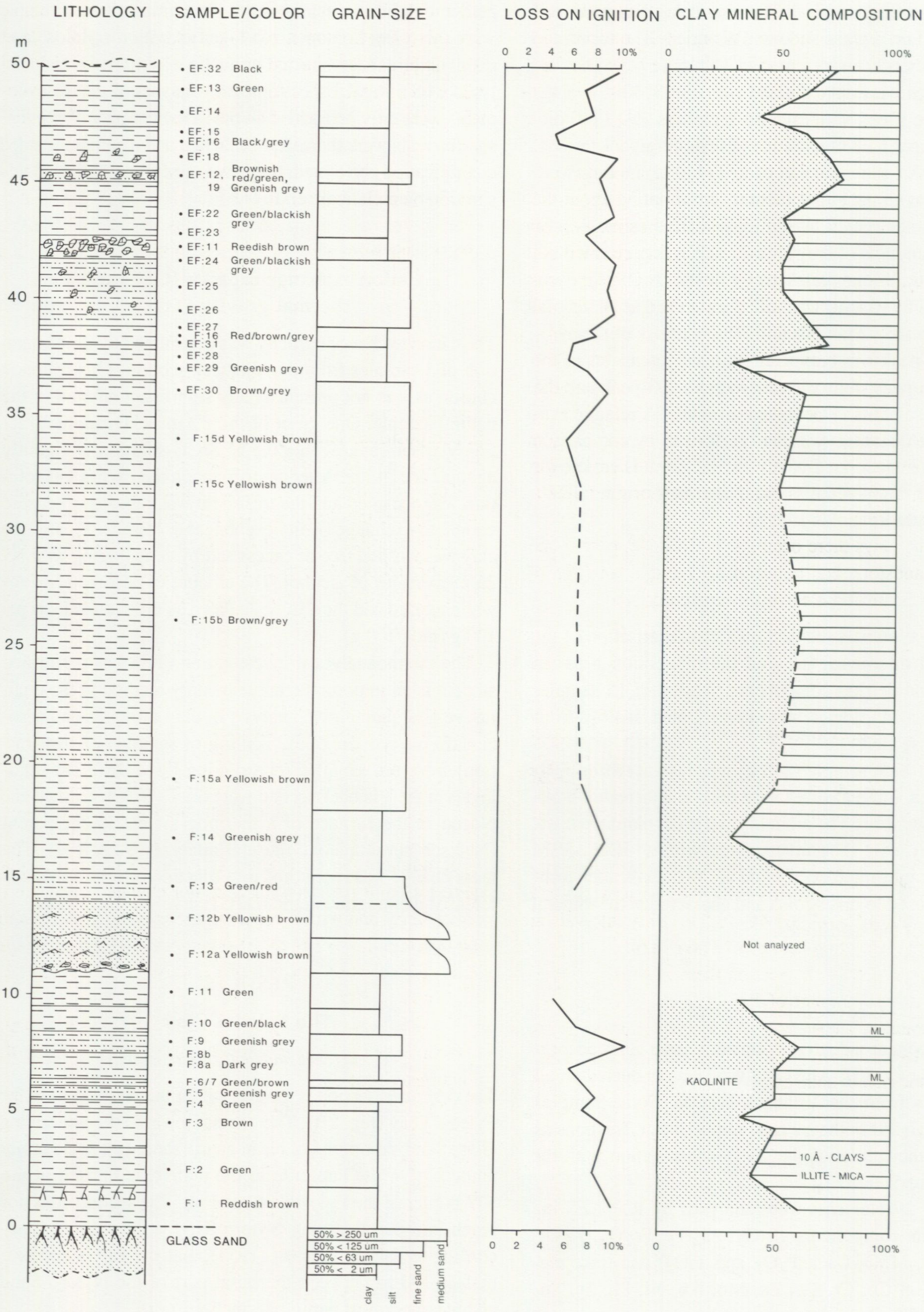


Fig. 4. General petrological chart for the Fyledal Clay section.

often between 0.5 and 2 m. The strata are vertically tilted and slightly overthrusted to the SW and strike on average N 40° W. Thicker (at least 1 m thick) beds are generally laterally persistent, at least over distances up to a couple of hundred metres. The lithology in a borehole drilled in 1986, in the southeastern vicinity of the Fyleverken sand pit, correlates well with the basal part of the investigated section.

As illustrated in Fig. 4 most of the investigated section is composed of greenish grey, brown and black clays. The section is characterized by alternating distinct beds with different colour. The greenish grey and black clays dominate. Brownish lithologies occur only as minor beds and as inclusions in the section. Between 18 and 38 m the section is composed of reddish brown and greenish grey mottled clay. Reddish brown spots are spread throughout the heterogeneous interval. The sediments in this interval (18-38 m) are strongly affected by weathering in a 0-0.5 m thick zone, immediately beneath the Quaternary deposits. There are also thick debris flow deposits of Quaternary origin covering parts of the interval.

Beside the clays there occurs a 2.5 m thick, poorly consolidated sandstone bed between 11.5 and 14 m (Fig. 4). This bed, as similar thinner beds in an excavated area 200-300 m to the NW, is laterally wedging out and gives the bed a lens-shaped structure. This bed is the only sandstone observed within the section. Thin ironstone/sandstone beds, 10 to 20 cm thick, are found in nearby located smaller outcrops at levels corresponding to the basal part of the section. These beds seem to be very locally developed and change in character over short lateral distances. It is most likely that these ironstone beds correspond to silty intervals in the investigated section, e.g. F:9 (Fig. 4).

Silt and fine-grained sand are overall important constituents in most beds. Dominantly silty beds occur at 5.5–6.2, 7.5–8.5, 14–15, 40.5–44 and 46–46.5 m. Silty intervals are also found in the section between 18 and 38 m.

In the upper part of the section there are two clay beds containing a high amount of light grey, sligthly greenish carbonate nodules. The amount of nodules varies but at least one bed, between 42 and 43 m, seems to be relatively well developed and rich in nodules.

No macrofossils have been found in the section during this investigation. Christensen (1968), however, found numerous partly dissolved mollusc shell fragments at approximately 8 m from the contact to the Glass Sand. Oertli et al. (1961) also described a fossiliferous interval at the same level.

The organic content is significant, especially in the black beds. Beside a few rootlet horizons, the organic material is generally dispersed in the sediments and has a fine-grained appearance. No macrofloral fossils have been found.

The characteristics of the section are quite similar to those of the Fyledal Clay documented from boreholes, i.e. Karindal No. 1 and Åstorp No. 20 in the Ängelholm Trough (Guy-Ohlson & Norling 1988; Norling & Wikman 1990), Rydebäck-Fortuna core No. 5 in the Danish Subbasin (Norling 1972, 1981), and Assmåsa-1 and Snaven-1 in the Vomb Trough (Chatziemmanouil 1982; Norling 1981).

In Scania the Fyledal Clay is usually between 16 and 70 m thick (borehole data). In the Vitabäck-Eriksdal area, however, it has an estimated thickness of 140 m (Nilsson 1953). This estimation is, however, not based on a continuous section and therefore subject to some uncertainty.

Clay mineralogy

The clays in the investigated section are relatively uniform in composition. The clay-fraction (<2 µm) constitutes generally between 60 and 80% of the bulk samples.

There are only some minor variations in the relative quantities of the different clay mineral types in the <2 µm fraction. Kaolinite and 10 Å-minerals, mainly illite, dominate throughout. At certain levels (e.g. F:8a, F:10, EF:13) there occur slightly swelling randomly mixed layer (smectite-illite) minerals. These constitute, however, only small subordinate amounts in the respective sample. A semiquantitative estimation of the clay mineral composition indicates a slight predominance of 10-Å minerals over kaolinite in most of the investigated samples (cf. Fig. 4).

The degree of crystallinity of the clay minerals is higher in the 2–10 µm fraction than in the <2 µm fraction. There are also some quartz and feldspar, mainly potassium varieties, present in this fraction (cf. F:11, 2–10 µm; Fig. 7).

Throughout the section the X-ray diffractograms display quite a similar pattern without major changes in degree of crystallinity and with a constant intensity relation between the 001 and 002 peaks of 10-Å minerals. The peak shapes indicate a clear dominance of illite over well-crystallized mica in most samples.

Fig. 7 illustrates two representative X-ray diffractograms from the lower (F:11) respectively upper (EF:17) part of the investigated section.

The different colouration of the clays in the section does not seem to be related to any significant variation in any of the analysed elements. Instead it is most likely that there is a correlation between different types of iron minerals. Brownish beds frequently contain higher amounts of Fe^{3+} while dark-grey and green beds contain more Fe^{2+}. Green beds are also generally devoid of organic matter and sulphides contrary to the dark grey and black beds in the sequence. This colouration does seem to be, at least for the clays, primary and thus related to a reducing original depositional environment. Illite-rich beds could also give a predominant green colour (McBride 1974). This seems to corre-

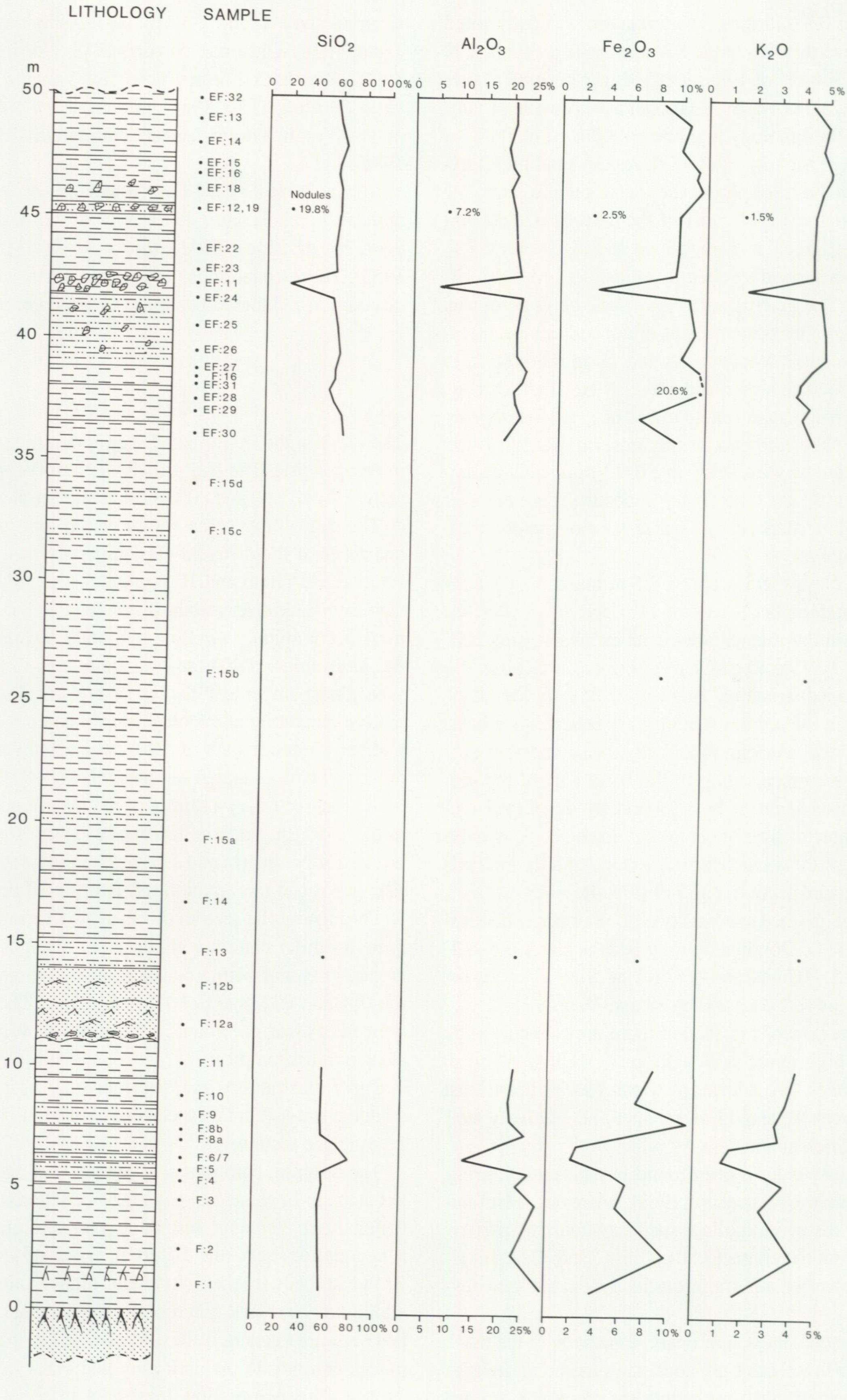
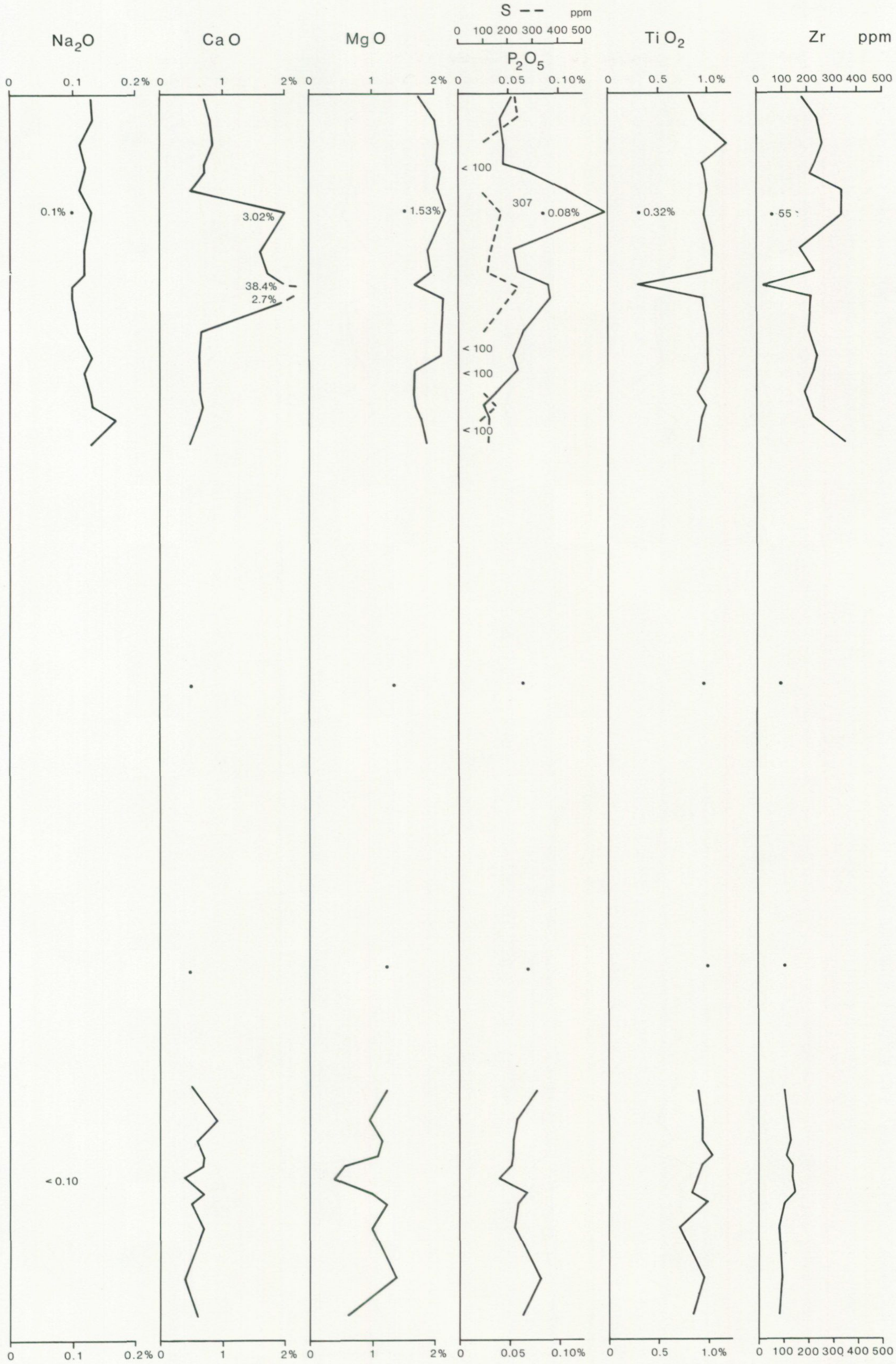


Fig. 5. Geochemical composition of the Fyledal Clay Section, main elements.


Na2O
Ca O
Mg O
S -- ppm
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P2O5
Ti O2
Zr ppm
0 0.1 0.2%
0 1 2%
0 1 2%
0 0.05 0.10%
0 0.5 1.0%
0 100 200 300 400 500
< 100
0.1%
3.02%
1.53%
307
0.08%
0.32%
55
38.4%
2.7%
< 100
< 100
< 100
< 0.10

Fig. 5, cont.

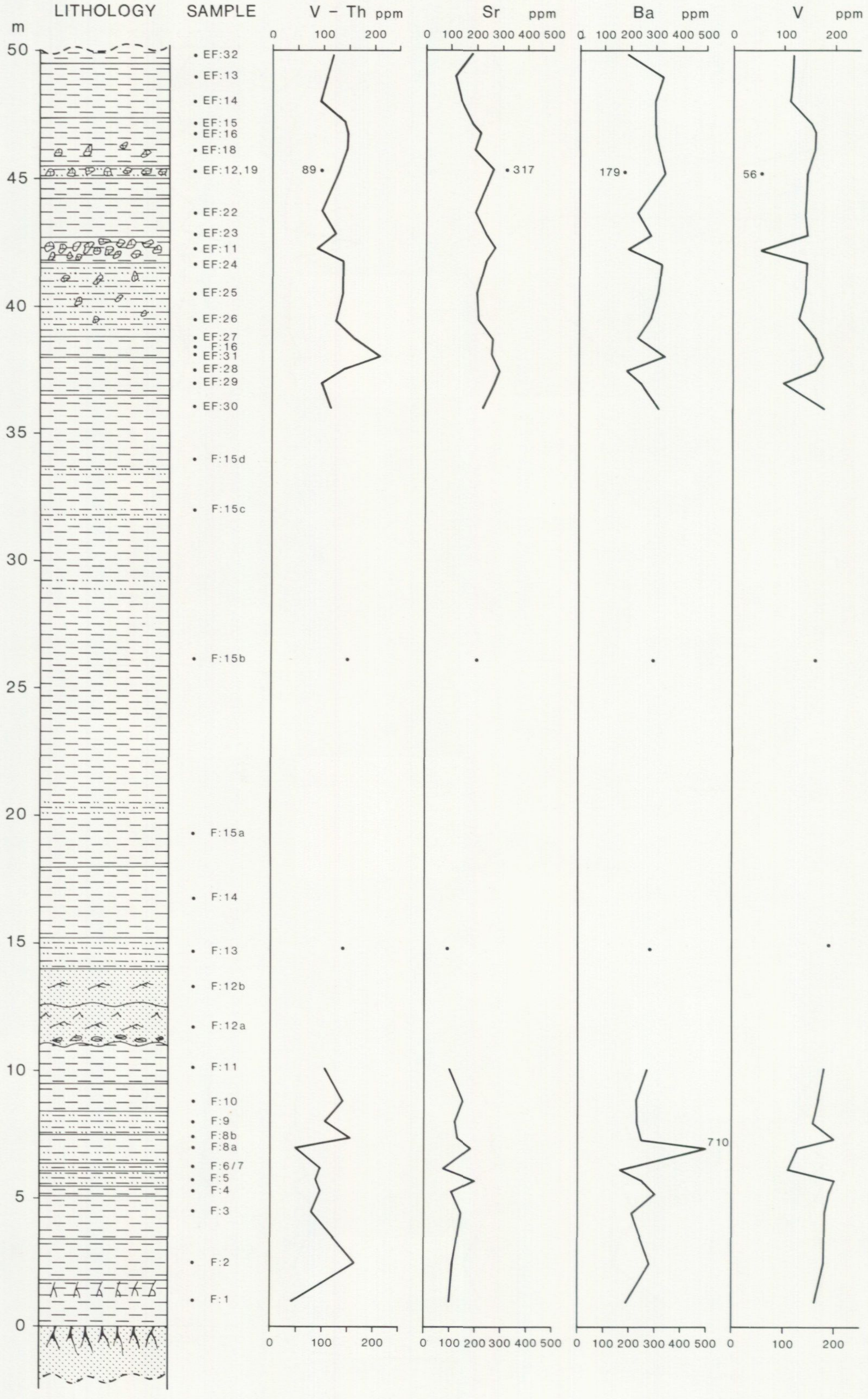

Fig. 6. Geochemical composition of the Fyledal Clay section, trace elements.

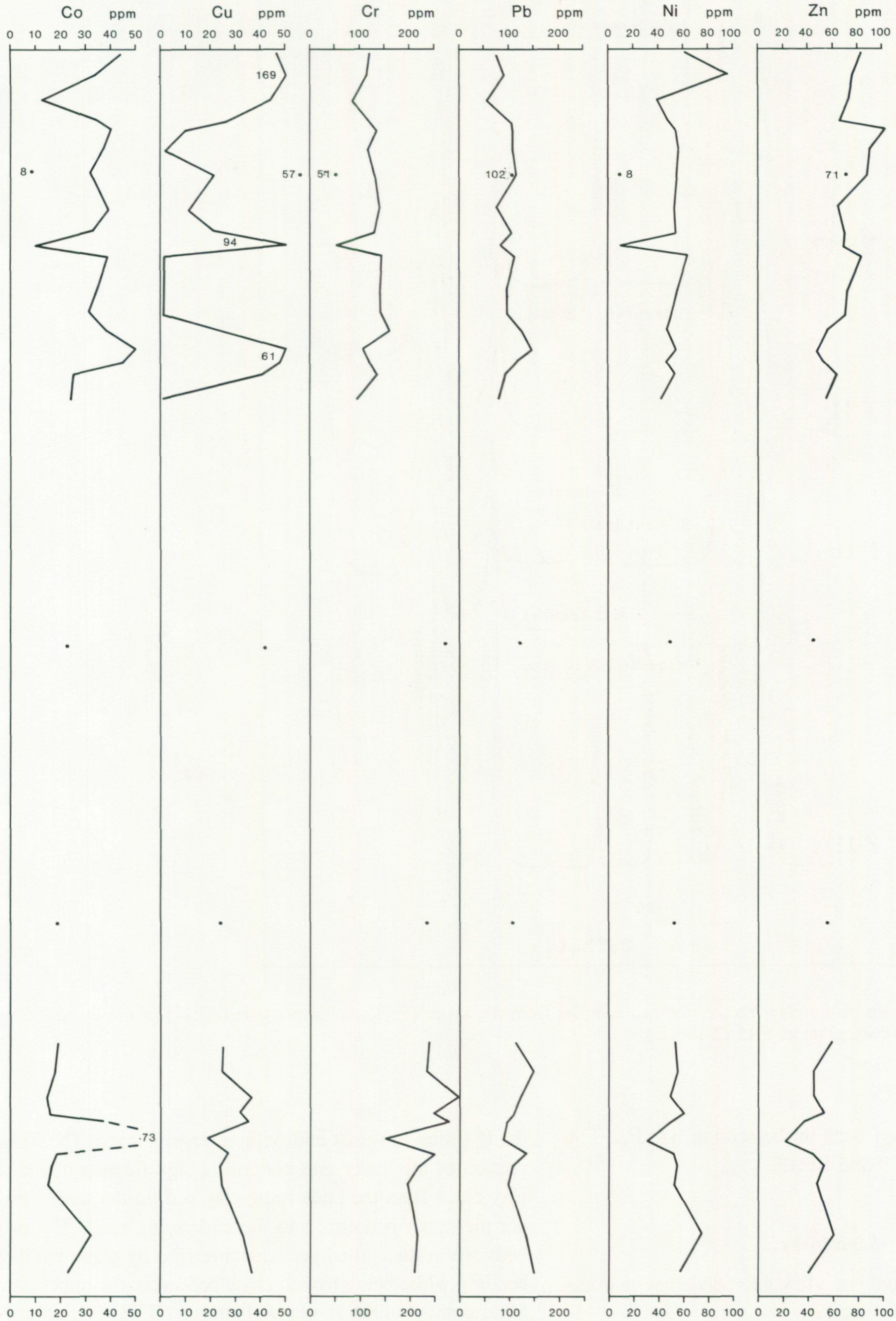
Co ppm
Cu ppm
Cr ppm
Pb ppm
Ni ppm
Zn ppm
0 10 20 30 40 50
0 10 20 30 40 50
0 100 200
0 100 200
0 20 40 60 80 100
0 20 40 60 80 100
169
94
61
8
57
51
102
8
71
73

Fig. 6, cont.

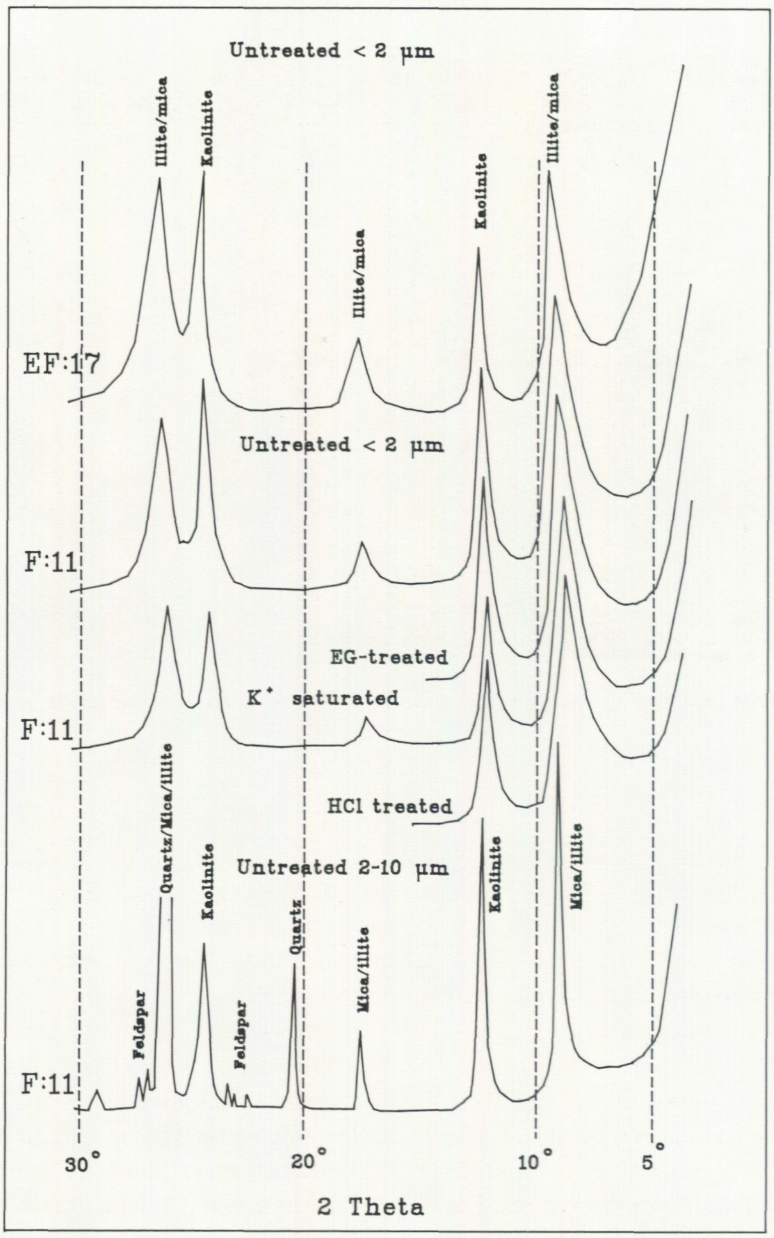

Fig. 7. X-ray diffractogram of the clay fraction for two samples from the lower (F:11) and upper part (EF:17) of the Fyledal Clay section and the X-ray diffractogram of F:11 (2-10 μm).

late well with the green beds in the section, i.e. F:2, F:4, F:10, F:11, F:14, EF:29 and EF:13.

Sandstones

Sandstone beds occur only as a few interbedded units in the otherwise clay dominated section.

The sandstone sequence between 11.5 and 14 m in the section is composed of two superimposed beds of medium and fine-grained poorly consolidated sand. The sequence is overall greyish. Reddish pigmentation gives the sequence, at least partly, a mottled colour. The beds are about equally thick, fining upwards and with an erosive base. The basal portion of the lower unit contains a significant amount of clay clasts from the underlying clay bed. In the same manner the upper bed cuts into the underlying sand. The two beds are in their basal part characterized by plane parallel bedding while being trough cross bedded in the upper part. Measurement of the ripples indicates a NE–SW palaeocurrent.

The sands are composed of subrounded to rounded quartz grains and some potassium feldspars. Especially in the upper part, however, there are significant amounts of matrix clay which drapes the ripple foresets. The upper boundary is

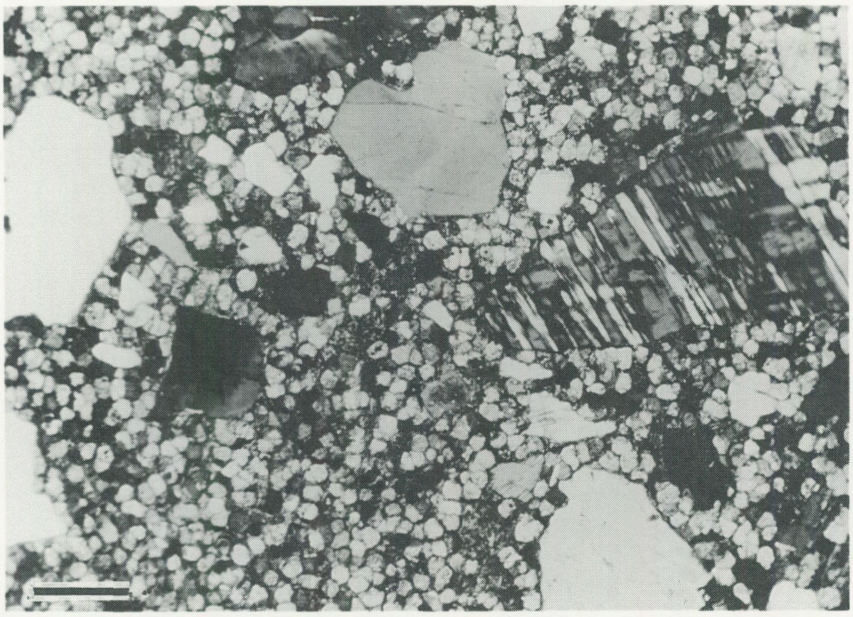

Fig. 8. Microphotograph of siderite cemented coarse-grained sandstone. Partly weathered microcline to the left of centre.

transitional into an overlying silty clay (F:13). The sandstone unit is laterally wedging out and transitions into silty and clayey, slightly brownish grey varieties. To the NW it seems to be developed as a 30 cm thick siderite cemented sandstone.

Siderite cemented, poorly sorted sandstone/ironstone beds have been sampled laterally from corresponding depths. These beds are laterally discontinuous and pass frequently into silty and fine-grained sandy, brownish beds. The beds are rich in iron, mainly siderite and Fe-oxyhydroxides. The beds are generally well indurated by siderite cement which is frequently weathered and altered into Fe-oxyhydroxides. The colour varies according to weathering from deep green to dark brown in the unweathered varieties to a reddish brown colour in the oxidized beds. The texture of the siderite cemented sandstone is characterized by medium- and coarse-grained detrital grains of mainly subrounded quartz floating in a cement of equidimensional siderite (Figs 8–9). A thin zone along the crystal interfaces is altered into Fe-oxyhydroxide. The grain-size of the detrital material indicates a mixing of two different detrital sources during deposition. Detrital glauconite is also found in these beds, indicating marine influences.

Calcareous beds

There are at least two intervals of the section that contain significant amounts of calcareous material. The lowermost interval is located at approximately 8 m from the base (i.e. F:9 and F:11 in Fig. 5). The other interval is located between 40 and 46 m (i.e. EF: 22–25). According to Christensen (1968) there is an additional calcareous bed similar to the basal interval (F:9–F:11) at approximately 16–20 m from the base. This bed was, however, not found in the present section.

The F:9–F:11 interval is characterized by three beds where the interlayered F:10 bed does not contain any significant amount of calcareous material. The carbonate content is in F:9 3.6% and in F:11 0.8% and is composed of whitish fine-grained material, most likely of finely fragmented fossil shell debris origin (Christensen 1968).

The upper interval between 40 and 46 m in the section is the most evidently calcareous interval in the section. It is characterized by at least two horizons with numerous carbonate nodules in a calcareous clayey-silty matrix. The nodules are especially enriched in beds EF:11 and EF:12 (Fig. 5) but are also found scattered in adjacent beds. The irregularly shaped nodules are light grey and slightly greenish, about 5 cm in diameter, relatively well indurated and with a uniform micritic texture. The nodules frequently contain microfractures filled with sparitic calcite and sulphide minerals (galena and pyrite). Chemical data (Table 1) show that they contain significant amounts of silica, alumina, potash and iron oxide. This is related to a significant amount of clay minerals (illite) in the micritic-like fabric. Besides some minor amount of sulphide related elements (Fe, Pb and Zn) there are no signs of enrichment of any other trace elements in the nodules.

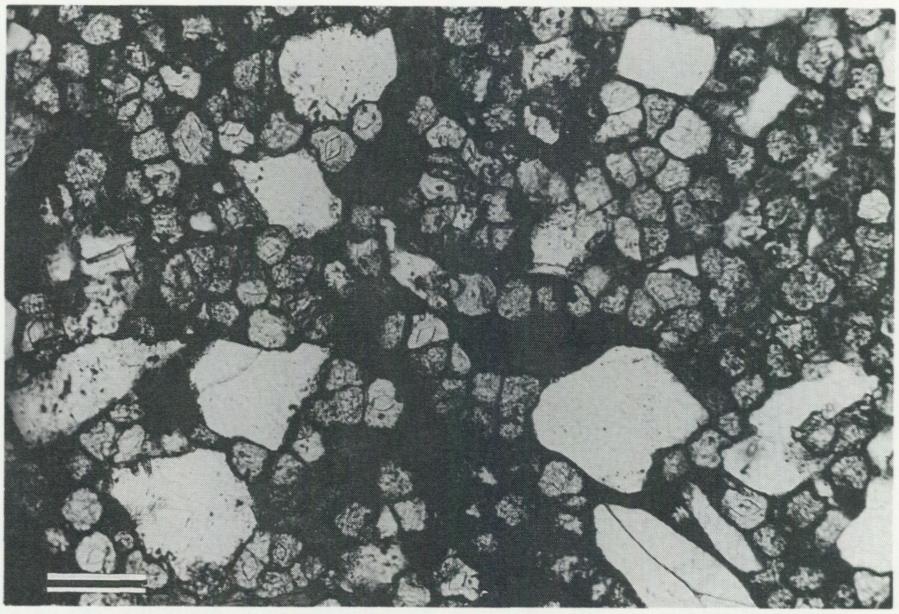

Fig. 9. Microphotograph of siderite crystal fabric. Rhombic crystal habit is weakly developed. Crystal interfaces are generally altered into dark brown Fe-oxyhydroxides.

TABLE 1. Chemical composition of three different carbonate nodule samples (A-C) from beds EF:11, EF:12 and EF:22.

	A	B	C
SiO_2	19.82	19.52	19.31
Al_2O_3	7.17	6.36	7.12
Fe_2O_3	3.13	2.49	4.20
Na_2O	<0.10	0.11	<0.10
K_2O	1.77	1.52	1.44
CaO	38.40	39.20	36.10
MgO	1.44	1.53	0.96
MnO	0.72	1.13	1.41
P_2O_5	0.089	0.087	0.99
TiO_2	0.32	0.32	0.23
S	0.024	0.031	0.042
CO_2	27.20	26.90	28.20
Sum	100.1	99.2	100.0

Overall geochemical composition

The chemical composition does not vary significantly within the section (Figs 4–6). Results from the lower, respectively upper and more completely sampled, intervals of the section show almost the same geochemical pattern. Thus, there was no major change of the geochemical environment during the deposition of the Fyledal Clay, at least for the basal 55 m. Measured deviations are mainly related to the calcareous and sandy/silty intervals in the section where some trace elements seem to be enriched (cf. Figs 4–6).

There are furthermore indications (XRD and chemical) of gypsum in connection with the calcareous nodular horizons in the upper part of the section. Nilsson (1953) also described gypsum crystals from this level.

A ternary plot (Al-Si-K) (Fig. 10) verifies that the Fyledal Clay is composed of a set of lithologies with approximately the same composition.

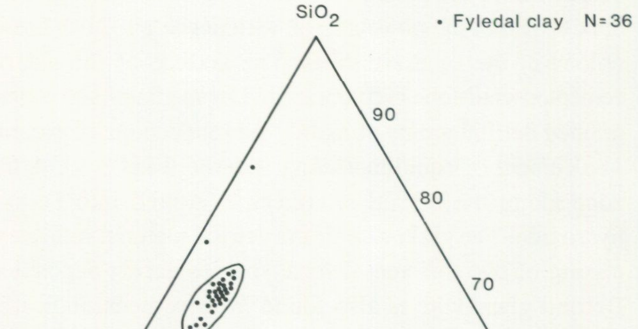

Fig. 10. Ternary plot (Al-K-Si) of the Fyledal Clay lithologies.

The Vitabäck Clays

Occurrence and field characteristics

The described section is located approximately 100 m WNW of the Eriksdal-Rödmölla (Fyleverken Mineral AB) cross-roads. The ditch section was opened in the field immediately north of the road to Rödmölla (Fig. 2A). The basal part of the section is located at the upper end of the field, close to an abandoned access road to the Fuglunda Farmhouse.

The Vitabäck Clays have earlier been described from several shallow pits and ditches in the area (Nilsson 1953). This section, however, is so far the most continuously exposed interval of the Vitabäck Clays. The exposed beds in the ditch strike on average N40°W and dip 80–70°NE. The beds are strongly affected by overburden gradient pressure and the superficial dip is significantly increased downslope. This has led to difficulties in establishing an exact individual thickness of the beds over intervals where caving in of water saturated Quaternary deposits made it impossible to excavate a ditch deep enough. One interval, between 5 and 8 m, caved in and thus no samples could be taken. The interval is composed of similar yellowish grey silty and fine sandy clayey deposits as E:5a. Observations during excavation indicate an upward fining trend. Sample E:5b corresponds to the uppermost part of the bed.

The basal part of the section is located at a brownish, clayey, fine-grained sandstone layer E:1 containing numerous shell fragments of molluscs (coquina bed). The layer is at least 30 cm thick. A similar but much thinner bed is located at 27 m (E:29). The succeeding beds are quite similar in character to the Fyledal Clay. The section is characterized, however, by more varied bedding, colouration and influence of coarser terrigenous clastic material (Fig. 11).

Even if greenish grey and dark grey to black clays dominate there are frequent reddish brown and yellow sandy silty beds interbedded in the section, e.g. E:8, E:10, E:11 and E:30 which are distinct reddish brown sandstones. The beds are on average between 0.5 and 1.5 m thick. Thicker beds include a sandstone bed between 20 and 22 m and the partly covered interval between 1.5 and 9.5 m (E:5a–5b).

The section contains several black and dark grey clays (i.e. E:3, E:11, E:19, E:25, E:28, E:31 and E:35). These beds contain frequent macrofossil plant fragments of unknown origin. Typical root horizons have not been found in the section. There occur, however, indistinct tube-like mottled textures in the uppermost part of the underlying bed of the black beds E:11, E:23-26, E:28. Such textures may be related to poorly preserved rootlet structures (see Fig. 11).

The section ends with bluish to greenish grey clays similar to those in the Fyledal Clay section. The bed is at least 1 m thick. Further excavation was prevented due to a thick cover of Quaternary deposits.

Nilsson's (1953) observations of the Vitabäck Clays were mainly derived from two pits, V5 and V4 (Fig. 2A). The composition is approximately the same at his localities as in the section described herein. Thus, there are alternating beds of clay and sand with organic debris and shell fragments of molluscs (mainly bivalves). Borehole investigations in the central parts of the Vomb Trough (e.g. Assmåsa-1 in Norling 1981) give a slightly more uniform clayey composition. In the Ängelholm Trough (Guy-Ohlson & Norling 1988; Norling & Wikman 1990) the Vitabäck Clays are at least between 30 and 47 m thick and composed of mainly reddish brown, greenish grey and black clays and siltstones. Thin coal beds and rootlet horizons are also common. Upper Jurassic – Lower Cretaceous beds of probable Vitabäck Clays facies are also found along the western slope of the Romeleåsen Horst (Norling in Ringberg 1976; Norling 1981 p. 262).

Clay mineralogy

The amount of clay sized material (<2 µm) varies greatly within the section, from less than 10% in reddish ferruginous sandstone beds (E:8) to over 80% in the pure clays (cf. Fig. 11). The clay mineral composition is dominated by kaolinite (7.2 Å), illite/mica (10 Å) and a mixed layer illite-smectite component (11–13 Å). The mixed layer minerals are slightly swelling but generally dominated by nonswelling illitic components. The 10-Å and mixed layer minerals (illite-smectite) are overall slightly dominating over kaolinite in the section. Characteristic XRD-curves are illustrated in Fig. 15. The variation found between samples seems to be repeated throughout the studied section. Mixed layer clays are found in almost all beds but are more frequent below reddish brown beds. The mica content of the clays is considerable in all samples. Fine-grained mica is an important component of the >10 µm fraction.

Microtexture investigation (SEM) of E:3, E:10 and E:29 (Figs 16–18) shows that the fabric is dominated by detrital illite and kaolinite. Kaolinite is occasionally found as large (50–60 µm in diameter) face to face stacks of pseudohexagonal crystals (Fig. 17). Illite is characterized by irregular clay platelets oriented more or less parallel to each other. The mixed layer component is developed as diffuse flaky, slightly crenulated aggregates. This texture is intermediate between the typical open web-like morphology of smectite and the more distinct flaky illite habit. In the clays there also occur numerous heavily corroded detrital feldspar grains (Fig. 18).

Cation exchange investigations of E:4 (kao=il=ml), E:19 (kao>ml>il) and E:22 (kao=il>>ml) yield the values 55, 65 and 42 meq/100 g respectively. The values are slightly higher than for pure illite and kaolinite and could thus be

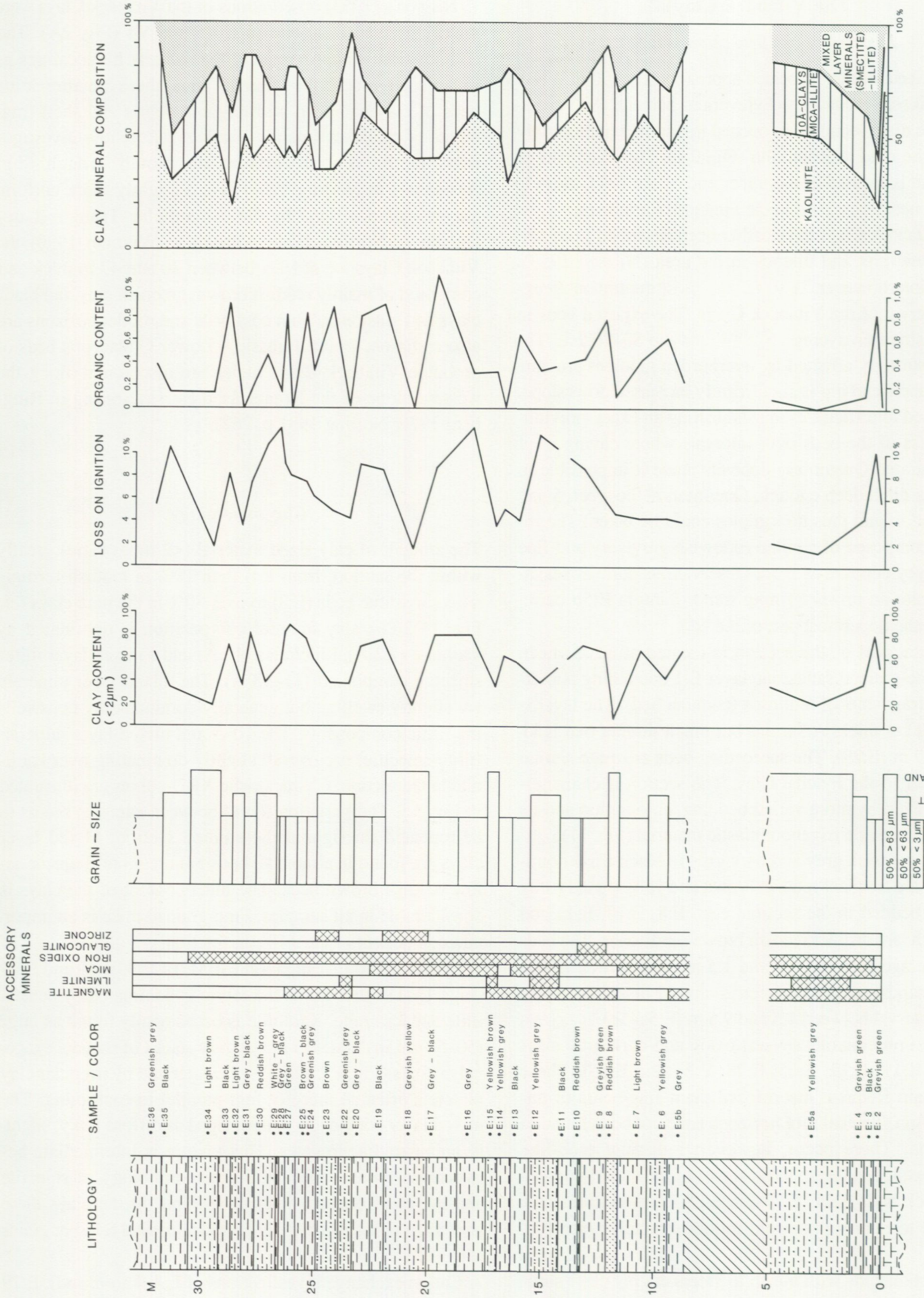

Fig. 11. General petrological chart for the Vitabäck Clays.

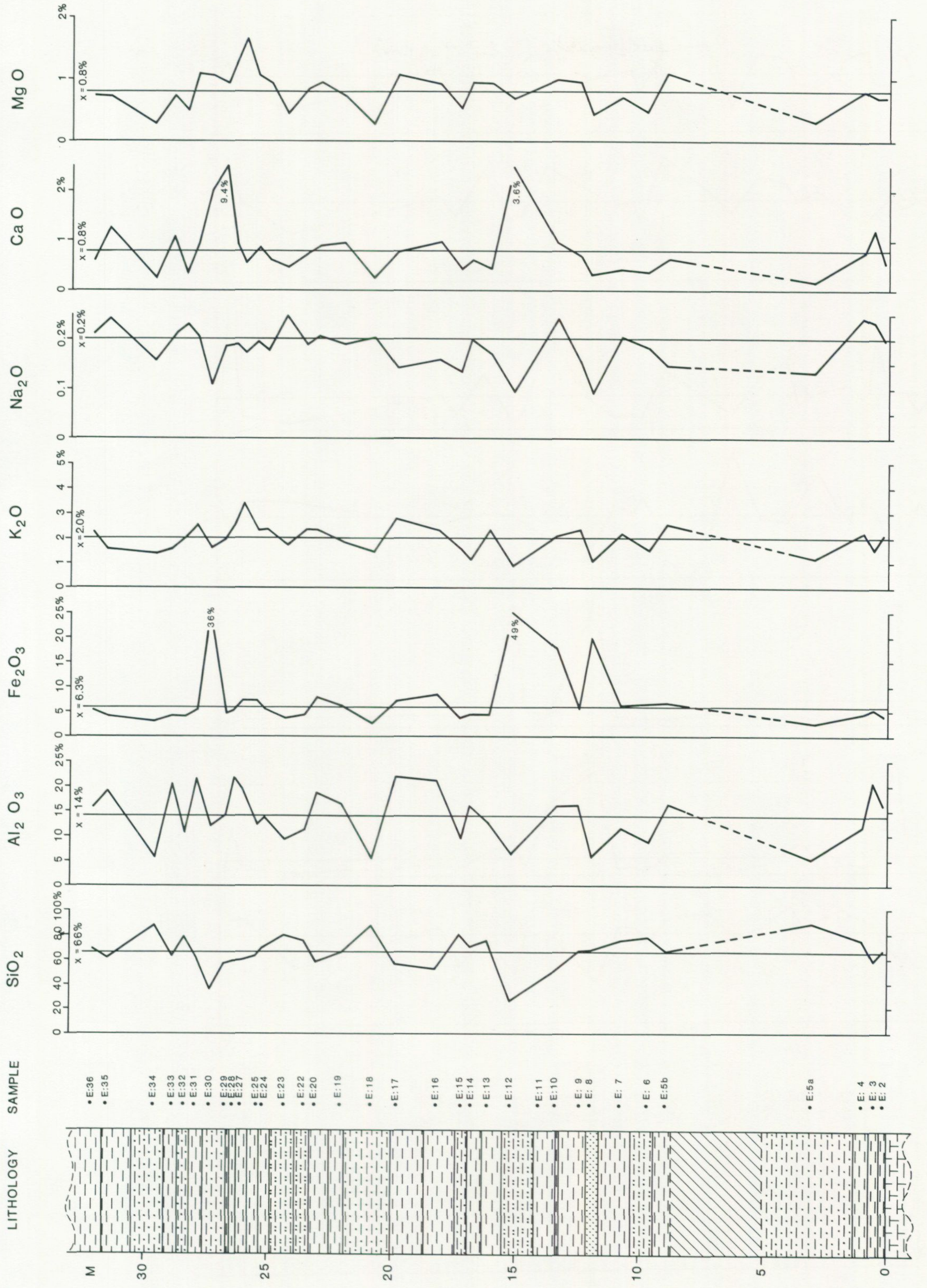

Fig. 12. Geochemical composition of the Vitabäck Clays, main elements.

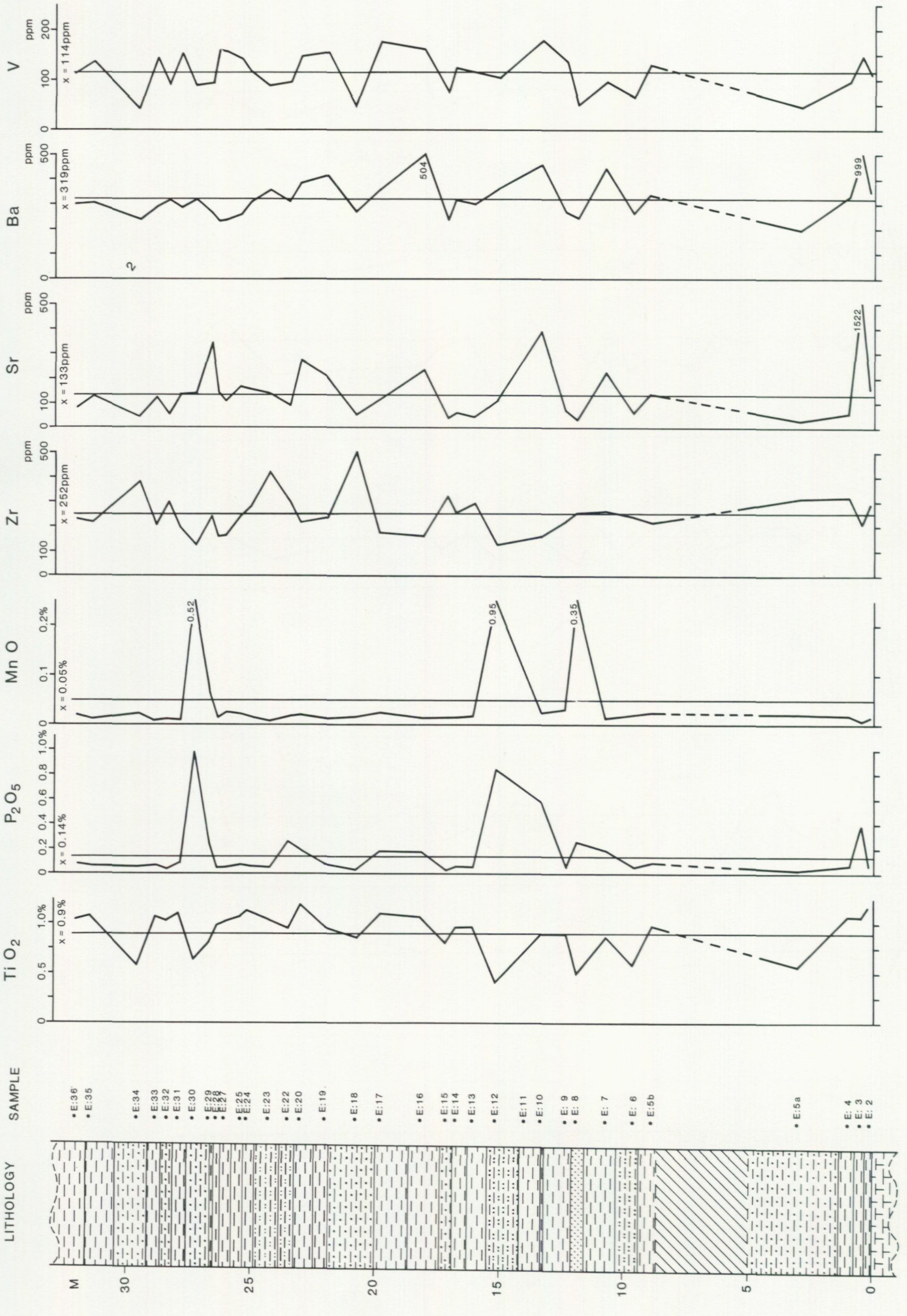

Fig. 13. Geochemical composition of the Vitabäck Clays, trace elements.

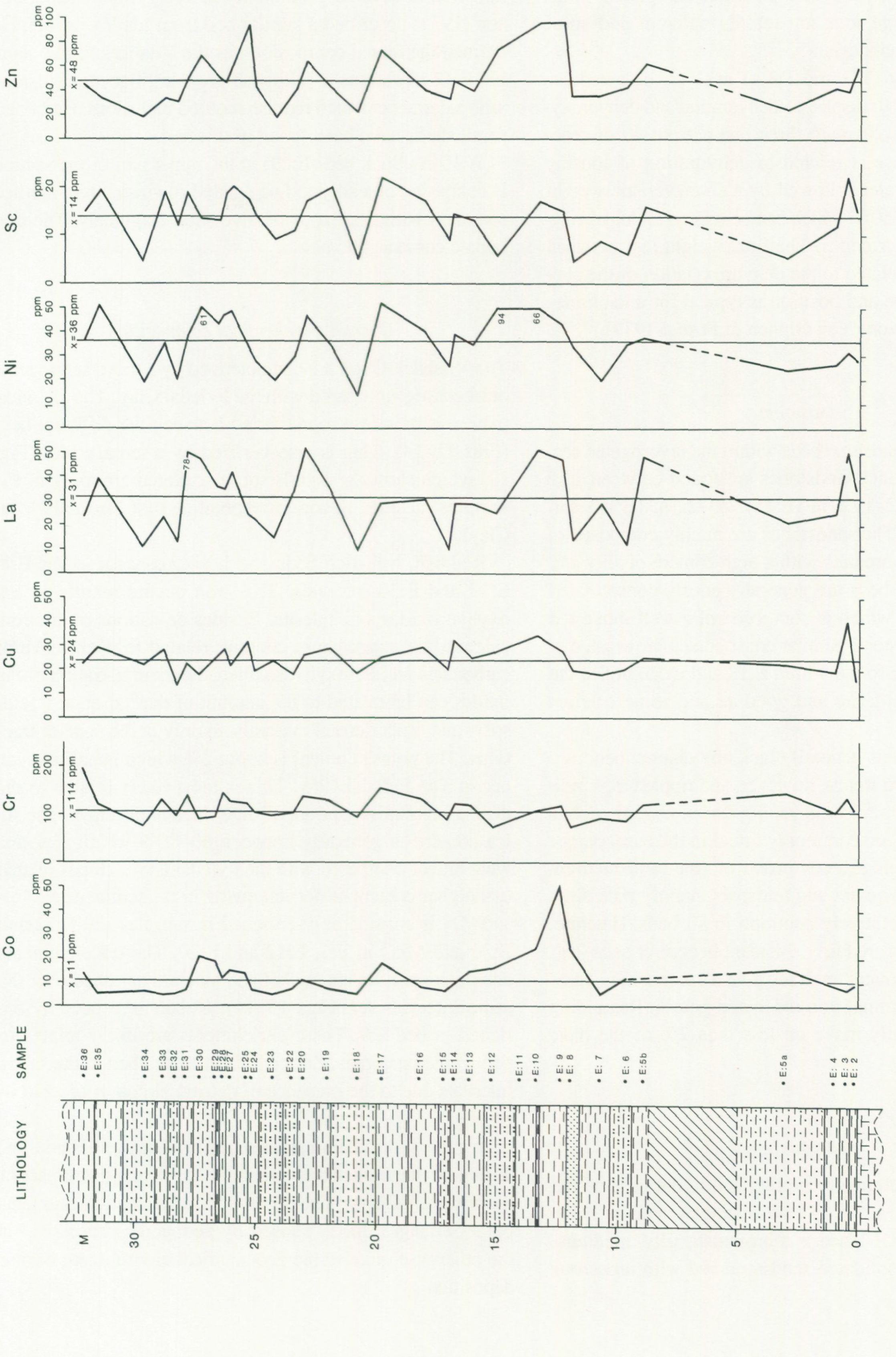

Fig. 14. Geochemical composition of the Vitabäck Clays, trace elements (continued).

explained by the mixed layer expandable component in the clays. The exchange ions are mainly calcium and some minor amount of magnesium.

Thermal gravity (TG and DTA) analysis of a reddish brown clay bed (E:10) displays a dehydration and dehydroxylation pattern (Fig. 20) with three distinct phases of reaction. The first phase is related to dehydration of loosely bound interlayer water followed by a characteristic weight loss between 300–350°C which can be related to dehydroxylation of Fe-oxyhydroxides. The final weight loss between 450 and 600°C is related to the dehydroxylation of the clay minerals. The shape and position is typical for a kaolinite-illite clay composition (Van Olphen & Fripiat 1979).

Sandstones

There are several sandstone beds within the investigated section (Fig. 11). Distinct sandstones are found between 11.5 and 12 m (E:8), 17–17.5 m (E:15), 20–22 m (E:18) and 29–30.5 m (E:34). The sandstones are mainly composed of fine-grained quartz arenites with a high content of silty and clayey matrix. The beds are generally poorly consolidated except for bed E:8 which is composed of a well indurated reddish brown sandstone. Similar consolidated brownish discontinuos layers are found within E:18 and E:15. In E:8 the cement is mainly siderite and goethite and some calcium carbonate (Fig. 21).

The sandstone beds generally lack any distinct bedding. Vague fining upward trends, however, and rippled tops indicate deposition from episodic vaning flows. Organic debris and shell fragments are commonly found in the basal parts.

The detrital grains are composed of fine- and medium grained subrounded quartz and feldspars, mainly potassium varieties. Mica is relatively common in all beds. Ilmenite, zircon and magnetite are fairly abundant in coarser beds (e.g. E:8, E:18). The chemical analyses give a composition dominated by silica, alumina, iron oxide and potash. Remaining components generally make up less than 2% of the bulk mass.

Calcareous beds

In addition to the reference coquina bed at the base of the section (E:1) there are only two distinctly similar beds, E:12 and E:29. The E:1 bed is a brownish, silty, medium-grained, poorly consolidated sandstone bed with numerous thin-shelled bivalves, commonly severely fragmented. Nilsson (1953) described a similar bed from his V4 profile. He defined the faunal composition as the Vitabäck fauna. Sample E:12 represents a yellowish grey, argillaceous siltstone with siderite cemented reddish mottled inclusions. Carbonate fossil shells have been found in this bed.

A 10 cm thick bed (E:29) in the upper part of the section is composed of a silty to fine sandy brownish white mottled sediment with numerous bivalve shell fragments. The carbonate content is 15%.

Overall geochemical composition

The Vitabäck Clays are characterized by a more heterogeneous bedding, compared with the Fyledal Clay. The chemical pattern is therefore more varied between the different beds (Figs 11–14). This is also verified by a ternary plot (Fig. 19) which shows a slightly more scattered grouping of the samples (cf. Fig. 10 for corresponding plot for the Fyledal Clay).

Reddish, iron-rich beds and horizons occur in the E:8-E:13 and E:30 intervals. This iron occurs mainly as Fe-oxyhydroxides and siderite. Besides deviations in the iron, calcium and magnesium content, related to occurrence of carbonates and Fe-oxyhydroxides, the main variation of the oxides can be related to the amount of detrital quartz, feldspars and other detrital minerals, mainly in the coarser fractions. The potash content is about 2% which is half the values in The Fyledal Clay. This is most likely related to the decreased relative amount of illite/mica in the clays. The silica content is generally between 60–80% which is somewhat higher compared with the Fyledal Clay. This is related to a higher content of detrital quartz in the sediments.

P_2O_5 is considerably enriched in samples E:9-E:12 and E:30 and MnO in E:7, E:12 and E:30. The trace elements cobalt, copper, lantan, nickel and zinc are enriched over the same intervals (cf. Figs 13–14). Cobalt is especially enriched in bed E:9. These enrichments are likely related to pedogenic processes. Zr and TiO_2 are enriched in the sandy intervals due to the presence of detrital zircon, rutile and ilmenite.

In general the chemical results show that there is no trend in any of the analysed elements in the investigated part of the Vitabäck Clays. The observed deviations indicate temporary changes, likely caused by pedogenic processes, in the otherwise quite stable geochemical environment during deposition.

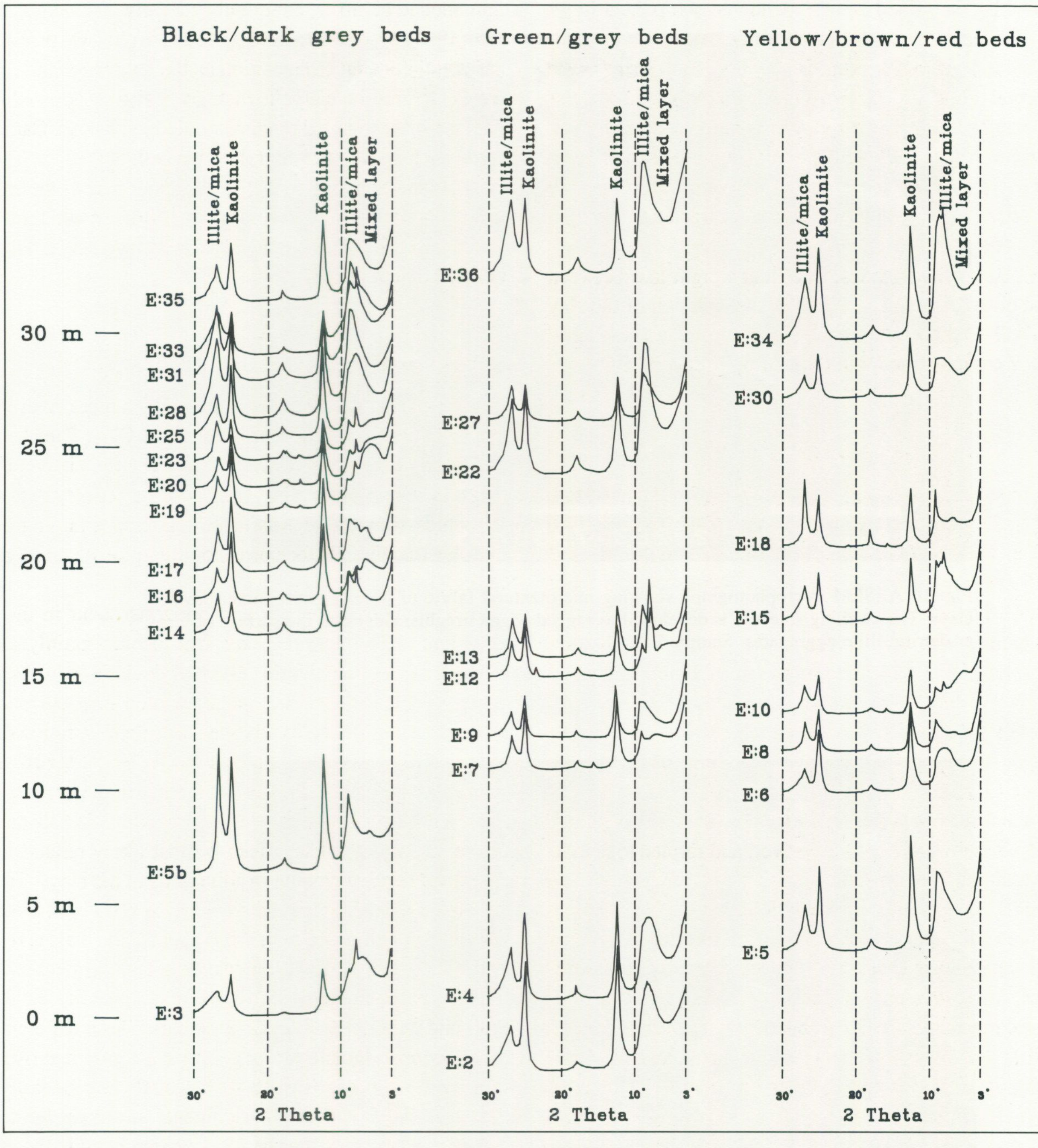

Fig. 15. X-ray diffractograms of the <2 μm fraction. The diffractograms display typical clay mineral composition at different levels of the described section.

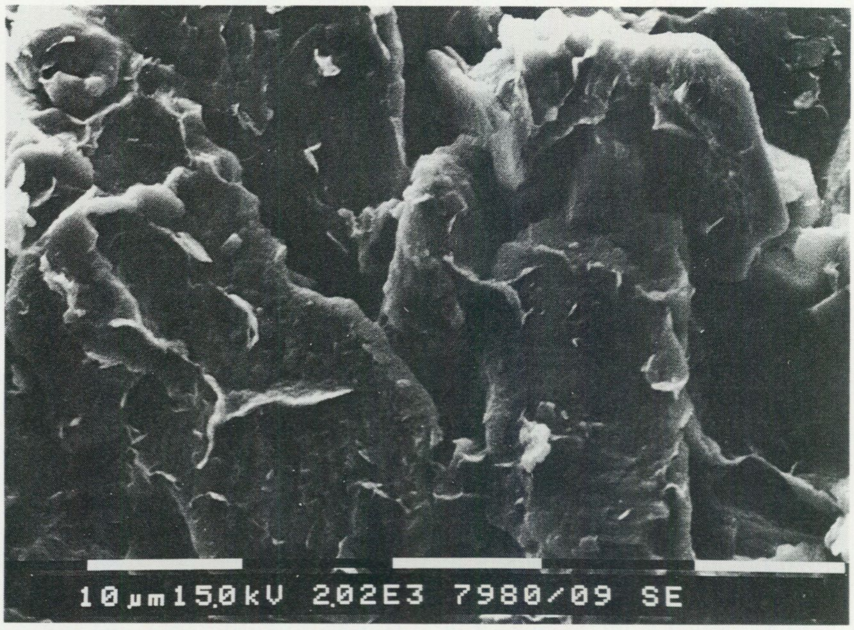

Fig. 16 A. SEM microphotograph showing microtextural fabric of illite/smectite mixed layer clays. The swelling smectite is developed as ragged edged irregular ridges on the surface of larger detrital illite aggregates. Sample E:3.

Fig. 16 B. SEM micrograph of sample E:16. Illite/smectite mixed layer clays.

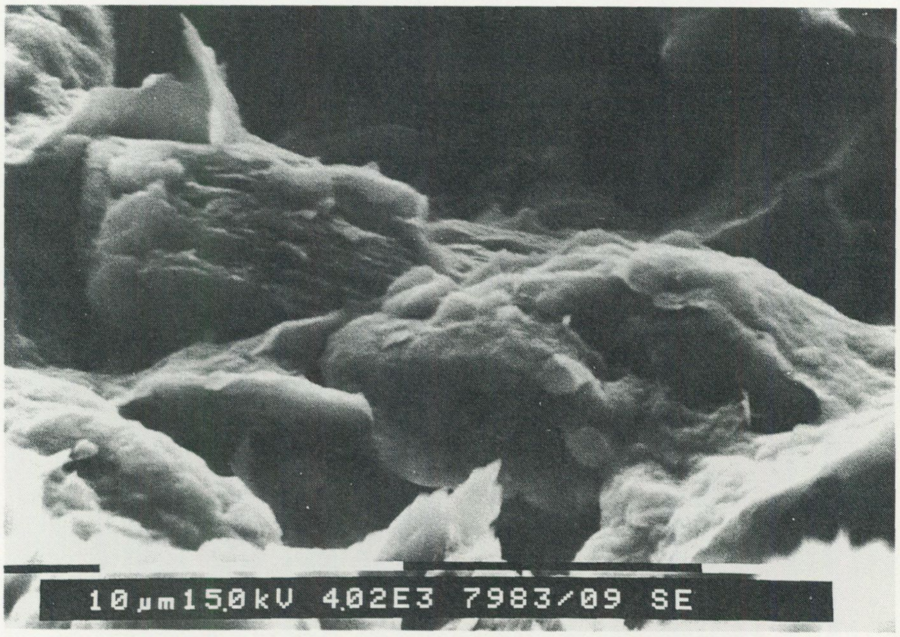

Fig. 17. SEM microphotograph showing microtextural fabric of pseudohexagonal platelets of kaolinite arranged face to face. Sample E:3.

Fauna and flora

The palaeontological investigation aims to document and determine the fossils found and to biostratigraphically confirm and narrow the age determination of the examined sections. It is hoped that the results will contribute to the information concerning the palaeoenvironment and sedimentary deposition of the samples studied.

MOLLUSCS

All of the described material comes from samples collected by Nilsson during the period 1939-52 from the Vitabäck Clays, localities V4, 5, 6, 8, 9, 10 and 11 (Fig. 2A; Nilsson 1953). The fossils are generally poorly preserved due to dissolution and fragmentation. The fauna has been described by Hägg (1940) and by Ekström (1985). The bivalves are dominated by representatives of the *Myrene, Isognom* and *Neomidon* genera and the gastropod specimens come mainly from the genera *Hydrobia, Ptychostylus, Valvata* and *Cloughtonia*. Ekström´s description has yielded a fauna composed of species indicating mainly brackish environments. The stratigraphical use of the material is very restricted since the species found are few, of wide stratigraphical range and dependent on environmental factors. Comparison of this molluscan assemblage with similar faunal assemblages in northwest Europe, however, may indicate that the Vitabäck Clays are of Early Cretaceous age (Dörhöfer & Norris 1977; Huckriede 1967).

The following bivalve taxa were identified by Ekström (1985):

Myrene angulata (Roemer 1836)
Isognomon sp.
Neomiodon cf. *orbicularis* (Roemer 1836).
Jurassicorbula sp.
Ostrea sp.?
Quenstedtia sp.?
Integricardium sp.?

The following gastropod taxa were identified by Ekström (1985):

Cloughtonia sp.
Hydrobia cf. *acuminata* (Dunker 1846)
Ptychostylus harpaeformis (Koch & Dunker 1837)
Valvata cf. *helicelloides* (Huckriede 1967)
Amplovalvata valareslebensis (Huckriede 1967)
Physa sp.?
Theodoxus sp.?

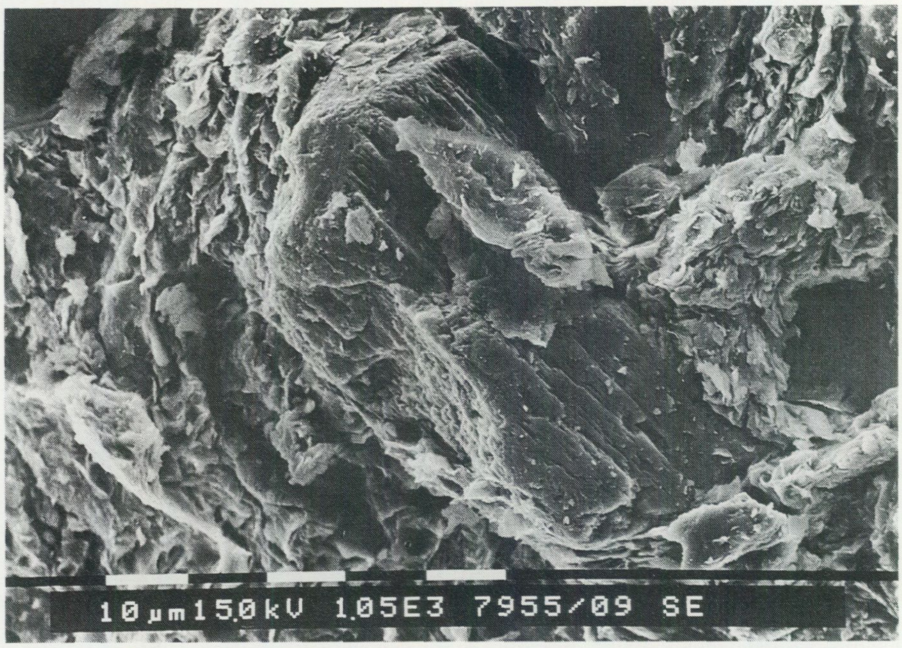

Fig. 18 A. Remnants of a detrital feldspar grain are seen in the centre of the microphotograph. The former grain is almost completely corroded. The preferred orientation of the remnants suggests a crystallographically controlled dissolution process. The grain is surrounded by massive detrital illite and kaolinite, and illite-smectite mixed layer clay minerals. Sample E:10.

Fig. 18 B. Feldspar dissolution in a sample from the upper part of the section. Similar process of corrosion is here observed on a much larger grain. Sample E:29.

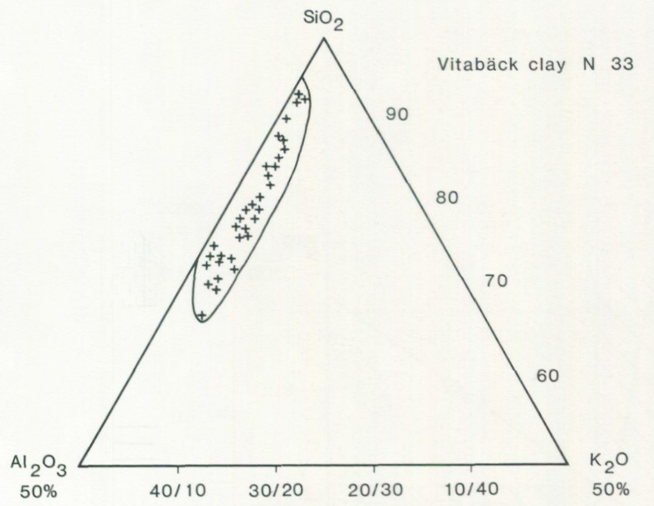

Fig. 19. Ternary plot (Al-K-Si) of the lithologies of the Vitabäck Clays.

OSTRACODES

Material and methods

Details of the exact position and the lithology of each sample in the section are to be found in Figs 4 and 11. Approximately 150 grams of each sample were processed using standard methods (Sivhed 1980).

The ostracodes illustrated in Plate 1 are to be deposited at the Geological Survey of Sweden, Uppsala.

The Fyledal Clay

Ostracodes have earlier been recorded from the Fyledal Clay at Eriksdal by Oertli et al. (1961) and Christensen (1968). Though several samples have been analysed, very few ostracodes have been recorded. These are restricted to a limited number of taxa. As the ostracodes in many cases are poorly preserved the determination of them may sometimes be questionable.

Most of the species have earlier been described by Christensen (1968) from the Vitabäck Clays in Scania and from the Rabekke Formation (Portlandian-Berriasian in age, see Gravesen et al. 1982) on Bornholm. Along with other ostracode species indicating a Late Jurassic – Early Cretaceous age, *Scabriculocypris trapezoides* has been recorded from the western slope of the Romeleåsen Horst (Norling 1981).

The present ostracode fauna consists of other species than those previously described from the same formation at Eriksdal and other places in Scania and in the Sound (Oertli et al. 1961; Christensen 1968). It is more reminiscent of the fauna recorded from the Vitabäck Clays at Eriksdal (Christensen 1968). The fauna contains several species recorded in Kimmeridgian - Berriasian strata elsewhere in Europe (Fig. 22; see for instance Ainsworth et al. 1989 and references in that publication). According to its ostracode content, the sampled level in the Fyledal Clay at Eriksdal may have an age ranging from Kimmeridgian to Berriasian.

The record of *Macrodentina* . cf. *rudis* might indicate restriction to a Kimmeridgian age for, at least part of the Fyledal Clay, as suggested by Christensen (1968) and Norling (1981). The single specimen of *M.* cf. *rudis*, however, is a larva which cannot be satisfactorily determined as to species.

The ostracode fauna indicates an oligohaline or perhaps a mesohaline environment at the time of deposition (see Christensen 1966; Barker 1966).

List of ostracode species recorded in this investigation:

Damonella cf. *pygmaea* (Anderson, 1941):
Sample EF:18, EF:19.
Damonella sp. 1142 Christensen 1968:
Sample EF:18:, EF:19.
Rhinocypris jurassica (Martin, 1940):
Sample EF:18, EF:19, EF:22.
Fabanella polita ornata (Steghaus, 1953):
Sample EF:18, EF:19, EF:22, EF:23.
Scabriculocypris trapezoides Anderson, 1941:
Sample EF:18, EF:19.
Klieana alata Martin, 1940:
Sample EF:18, EF:24.
Macrodentina (Polydentina) cf. *rudis* Malz, 1958:
Sample EF:18.
Exophthalmocythere sp.:
Sample EF:23.

The Vitabäck Clays

Very few ostracodes have been obtained from the Vitabäck Clays and therefore there is nearly no new information to add to that of Christensen (1968). The exact distribution of those found is given in Fig. 22. The stratigraphic ranges of these species (also given in Fig. 22 for comparison) shed no new light on the question of where to draw the Cretaceous–Jurassic boundary in the Vitabäck Clays. The fauna indicates a Late Jurassic – Early Cretaceous age of the member. According to Christensen (1974) the ostracode fauna is related to the "Middle and Lower Purbeckian and Portlandian" or in other terms Portlandian–Berriasian. The record of *M.* cf. *transiens* may restrict the sampled level (E:1) to the Portlandian Stage.

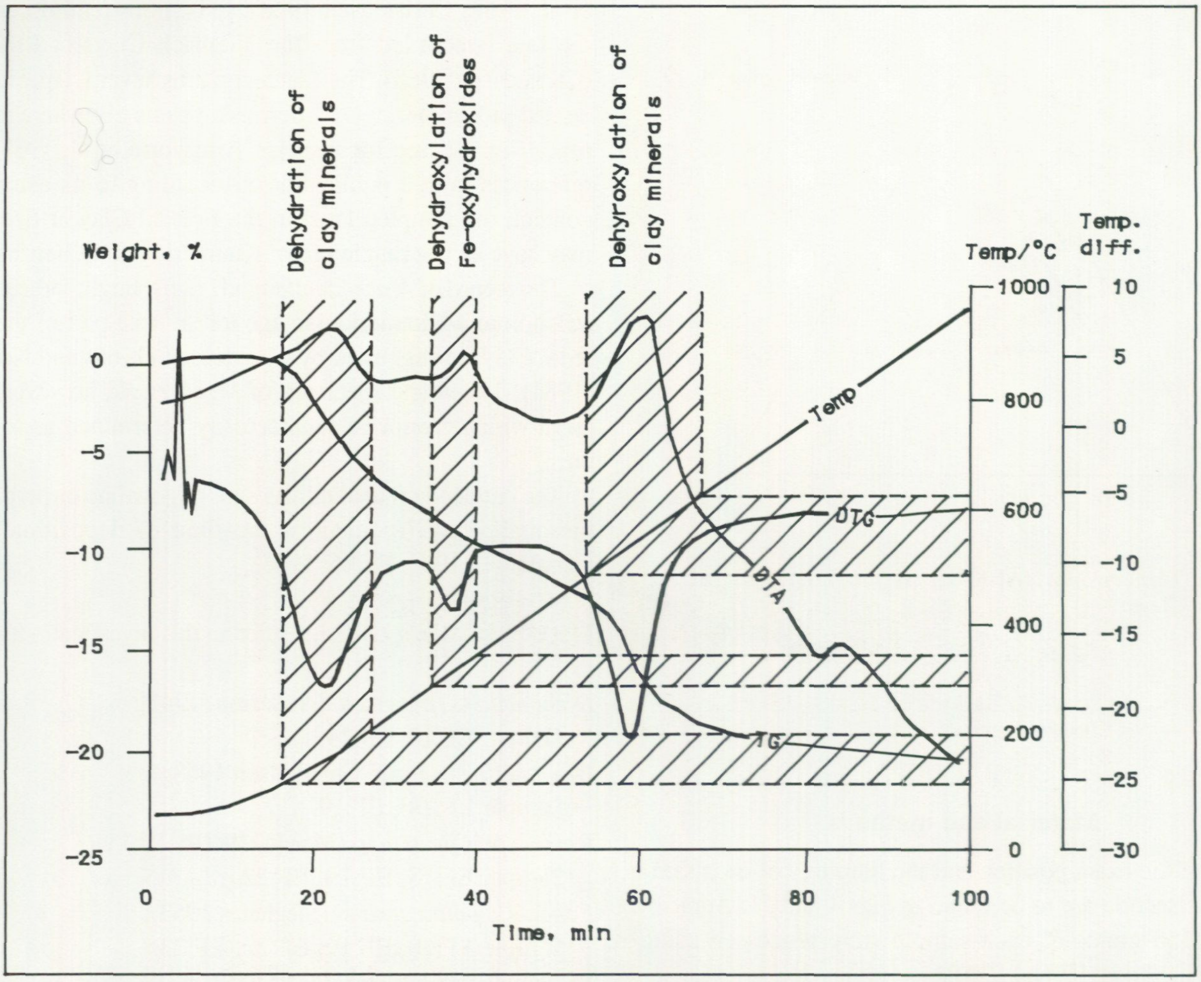

Fig. 20. TGA-curve of sample E:10. DTA = differential thermal graph, TG = thermogravimetric graph, DTG = differential gravimetric graph. Significant weight loss due to dehydration and dehydroxylation is visualized as drastic changes in the graphs.

As mentioned by Christensen (1968) the different fauna associations within the Vitabäck Clays indicate a varying saline environment at the time of deposition, from almost freshwater to marine. This conclusion is supported by the present investigation. The find of a single carapace preliminarily determined to the genus *Polycope* indicates a full marine environment. This find might indicate a redeposition of older sediment.

List of ostracodes recorded in this investigation:

Damonella cf. *pygmaea* (Anderson, 1941): Sample E:12.
Paracypris ? sp.: Sample E:22.
Klieana alata Martin, 1940: Sample E:1.
Macrodentina cf. *transiens* Jones, (1885): Sample E:1.
Polycope sp.: Sample E:12.

Ostracode stratigraphy at Eriksdal

The stratigraphic value of the treated taxa is restricted (cf. Fig. 22). As a general comment they are typical representatives of Upper Jurassic – lowermost Cretaceous strata elsewhere in Europe. There is, however, some ostracode evidence which might support a Kimmeridgian age for part of the Fyledal Clay at Eriksdal. The faunal composition within the Fyledal Clay and the Vitabäck Clays reflects different environmental conditions. An example of this is that most of the ostracode species here recorded in the Fyledal Clay were also found in the Vitabäck Clays by Christensen (1968).

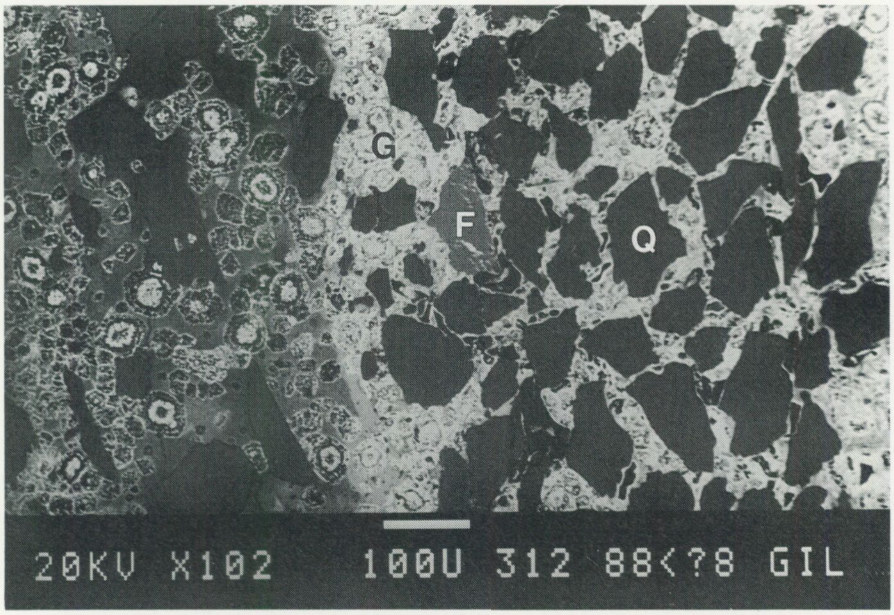

Fig. 21 A. Backscatter SEM microphotograph of a sandstone (E:8) with pores almost completely filled with acicular-like crystals of goethite (white areas) and amorphous hydrated iron compounds. Sphaerulitic aggregates of goethite occur within the amorphous part (right side).

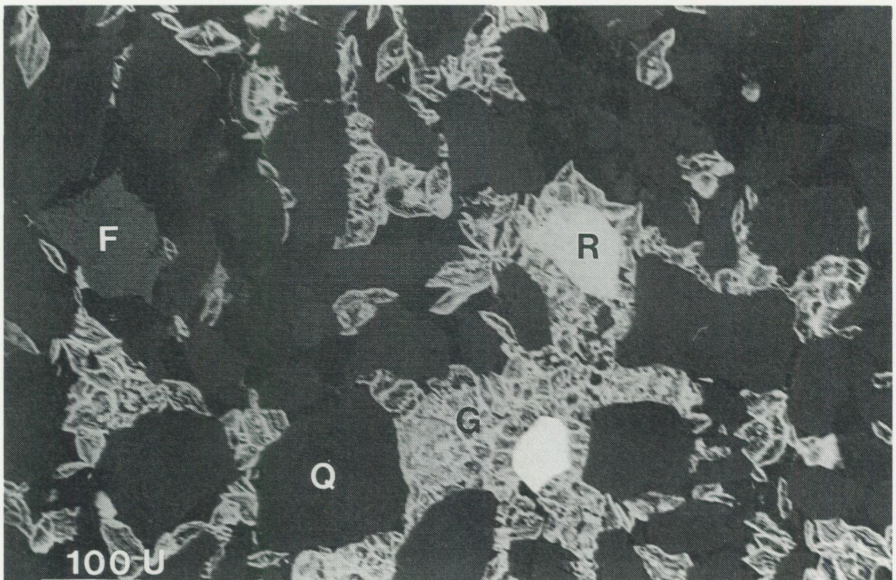

Fig. 21 B. Backscatter photograph of a poorly sorted sandstone (E:8) composed of dark grey subangular quartz grains, acicular whitish grey goethite crystals and bright white grains of rutile. To the left of centre a light grey feldspar crystal.

OSTRACODES FROM THE UPPER JURASSIC - LOWER CRETACEOUS TRANSITIONAL BEDS AT ERIKSDAL																
LIST OF OSTRACODES RECORDED FROM ERIKSDAL (present study)	STRATIGRAPHICAL RANGES IN EUROPE						FYLEDAL CLAY					VITABÄCK CLAYS				
	JURASSIC		CRETACEOUS				SAMPLES EF:					SAMPLES E:				
	KIMMERIDGIAN	PORTLANDIAN	BERRIASIAN	VALANGINIAN	HAUTERIVIAN	BARREMIAN	24	23	22	19	18	1	12	22		
Macrodentina (P.) *rudis*	—										●					
Rhinocypris jurassica		—	—	—	—				●	●	●					
Kileana alata		—	—	—			●				●	●				
Damonella pygmaea		—	—	—	—	—				●	●		●			
Fabanella polita ornata		—	—					●	●	●	●					
Scabriculocypris trapetzoides		—	—							●	●					
Macrodentina transiens		—	—									●				
Damonella sp. 1142			—							●	●					
Exopthalmocythere sp.								●								
Paracypris sp.														●		
Polycope sp.													●			

Fig. 22. Distribution of ostracodes found in the samples from the Fyledal Clay and the Vitabäck Clays and their stratigraphical ranges in Europe. See Figs 4 and 11 for the exact sample positions.

PALYNOMORPHS

Methods

Thirty-one of the thirty-six samples taken from the Vitabäck Clays section were selected for palynological investigation. Details of the exact position and the lithology of each sample in the section are to be found in Figs 4 and 11. Ten grams of each sample were processed using standard methods (Mädler 1984; Guy 1971; Guy-Ohlson et al. 1984). Ten slides were prepared from each residue and were examined by using transmitted light microscopy. So called strew stubs were also prepared from each residue for examination in the scanning electron microscope (SEM).

The sample material is the property of the Geological Survey of Sweden. The palynomorphs illustrated in Plates 2–7 are deposited at present for reference at the Section of Palaeobotany, Swedish Museum of Natural History, Stockholm.

Palynomorph content

The Fyledal Clay

In connection with several previous palynological investigations of Upper Jurassic sediments in Sweden (Guy-Ohlson 1985; Guy-Ohlson & Norling 1988) the type locality of the Fyledal Clay at Eriksdal was examined. Despite the fact that several new sections were exposed (cleared by bulldozer), and numerous samples collected, processed and examined, no palynomorphs whatsoever were found.

The Vitabäck Clays

During the light microscope analysis a total of 40 species of well preserved palynomorphs have been found in the 31 samples studied from the exposed Vitabäck Clays section. Though spores and pollen grains dominate the palynoflora, organic-walled microalgae were also recorded. A complete list of the species found is given in alphabetical order in the Appendix. Their distribution within the section is given in Fig. 23. The number of individual specimens recorded per species is also to be found in Fig. 23. Two coloured plates (2 and 3) exemplify the palynomorphs recorded during the transmitted light analysis, while plates 4, 5, 6 and 7 illustrate those found during examination of the samples in the scanning electron microscope.

Palynostratigraphy at Eriksdal

The Fyledal Clay

As previously mentioned no palynomorphs have been found in the Fyledal Clay at Eriksdal. In NW Scania, however, two assemblage zones, named A and B, of Oxfordian respectively Early Kimmeridgian ages have been established for the Fyledal Clay found at Karindal in NW Scania (Guy-Ohlson & Norling 1988).

The Vitabäck Clays

The distribution of the palynomorphs found in the samples is recorded in Fig. 23. From this table the following general points may be noted.

1) 40 species have been recorded and the number of individuals found per species is relatively low with the exception of the number of colonies recorded for the green alga *Botryococcus*.
2) Certain samples, namely E:4, 5, 8, 13, 15, 17, 18 and 22, are barren.
3) As one progresses from the older samples to the younger (i.e. from E:2 to E:36) there is a greater diversification of the number of different species present per sample.
4) There is an influx of species not previously recorded in the section at three points – at sample E:12, 25 and 28.

In Fig. 24 the species found have been arranged according to their known published stratigraphical range. From this figure it may be seen that almost half of the palynomorph species found are long-ranging. A few species commence their stratigraphical range at the end of the Jurassic, while others are restricted to or begin their range in the earliest Cretaceous. Combining the information in both figures several observations may be made.

a) The species found present up to sample E:9 are mostly long-ranging, but there are three species, namely *Concavissimisporites variverrucatus*, *Trilobosporites* cf. *canadensis* and *Leptolepidites psarosus*, which are indicative of a Late Jurassic-Early Cretaceous age (Norris 1969; Hunt 1985).

b) Of the five incoming species at sample E:12, *Trilobosporites obsitus* and *Cicatricosisporites australiensis* have been recorded from sediments of Early Cretaceous age (Hunt 1985).

c) Of the five incoming species at sample E:25, cf. *Leptolepidites epacrornatus* and *Trilobosporites aornatus* have been recorded in zones ascribed to the Purbeck Formation of southern England (Norris 1969; Hunt 1985).

d) Of the eight incoming species in sample E:28, two species, namely *Trilobosporites aequiverrucossus* and *Pilosisporites trichopapillosus*, have been recorded from a zone/suite equivalent to the middle of the Purbeck Formation , i.e. they indicate a Berriasian age (Norris 1973; Hunt 1985).

Thus the whole assemblage of palynomorphs found in the Vitabäck Clays section may be regarded as being of Late Jurassic – Early Cretaceous (Portlandian–Berriasian) age. Though there is the hint of the possibility of dividing the whole assemblage into two biozones this is refrained from partly because of the poverty in number of species found and number of individual specimens recorded per species and partly because a narrower age definition of specific samples is at present not advisable. This is due to the fact that no palynological definition of the boundary exists as a boundary stratotype has not yet been designated and internationally accepted (Batten 1978; 1991 – personal communication).

Palaeoenvironment

Though a few acritarchs have been found in samples E:12 and 31 (SEM examination only) no dinoflagellates have so far been recorded in the samples of the Vitabäck Clays at Eriksdal. Two species of other organic-walled phytoplankton, however, are of particular interest, namely the colonial green alga *Botryococcus* sp. and the unicellular green alga *Tasmanites*.

When found in palynological preparations *Botryococcus* is interpreted as indicating a freshwater influence on the depositional environment. From Fig. 23 it can be seen that *Botryococcus* has been found in 14 of the samples investigated. Large numbers of colonies have been found present in sample E:5b, 12 and 35. Hence, a substantial freshwater influence on the depositional environment may be interpreted for these samples.

Several developmental stages of colonial growth have been found in sample E:5b. From the excellent preservation of the colonies of this sample (Plate 6:5–13) it can be observed that several generations or "seasons" of growth have occurred before the final deposition of the colonies. A great deal of information is known about the growth and habitat of the extant alga *Botryococcus braunii* Kützing to which the fossil species is compared (Guy-Ohlson 1991). This alga is known at the present day to grow in a variety

LIST OF PALYNOMORPHS PRESENT	NUMBER OF PALYNOMORPHS IN SAMPLES EXAMINED (LIGHT MICROSCOPE ANALYSIS)																													
	2	3	4	5	5b	6	7	8	9	12	13	14	15	16	17	18	19	20	22	23	24	25	27	28	29	30	31	32	34	35	36
Botryococcus sp.	2				158	7	5			59				7			8	1			17	2			4	5		1		89	
Parvisaccites radiatus		1			6	13	2			8				2							1			3	1	1				5	
Dictyophyllidites equiexinus					8					1		1												1						2	2
Podocarpidites ellipticus					4																	1		8	2	1			1	6	
Araucariacites australis					1					1								1				1								4	
Concavissimisporites variverrucatus					1																										
Sp. indet 1					4	3			1																						
Gleicheniidites senonicus					2	2			2					1								4		11							
Trilobosporites cf. canadensis					1																										
Perinopollenites elatoides						5				1				4								2		3						1	1
Classopollis classoides						4				1										1		1		5	1	5				12	
Brachysaccus microsaccus						1				1				1										2	1					1	
Cerebropollenites mesozoicus						1																							1	3	
Leptolepidites psarosus									1																						
Trilobosporites obsitus										1																					
Trilobosporites sp. C										1																					
Tasmanites sp.										3																					
Cicatricosisporites australiensis										1																					
Callialasporites dampieri										1																				2	
Alisporites sp.										1												1		2						5	
Cyathidites australis														2																6	
Sp. indet. 2																	1						1								
Cf. Leptolepidites epacrornatus																						3		1							
Trilobosporites sp.																						1									
Cycadopites sp.																						3		2				1	1	5	
Trilobosporites aornatus																						1									
Cf. Sestrosporites pseudoalveolatus																						1									
Trilobosporites aequiverrucossus																								3							
Cyathidites minor																								3	2					1	
Eucommiidites troedssonii																								3	1					1	
Ginkgocycadophytus nitidus																								7							
Vitreisporites pallidus																								3							
Undulatisporites sp.																								12	4		1			2	1
Pilosisporites trichopapillosus																								5				1			
Cerebropollenites sp.																								2							
Lycopodiumsporites clavatoides																									1						
Trilobosporites bernissartensis																									1						
Trilobosporites sp. A																											3				
Ischyosporites sp.																														5	
Foraminisporis wonthaggiensis																														1	
TOTAL	2	1	-	-	185	36	7	-	4	80	-	1	-	17	-	-	9	2	-	1	18	21	1	76	18	12	4	3	3	152	4

Fig. 23. Distribution of palynomorphs found in the samples from the Vitabäck Clays. The sample numbers are given at the head of each column (see also Fig. 11).

of freshwater habitats from small ephemeral lakes, ponds, pools and ditches to large lakes and reservoirs. It is known to tolerate high salinities and to thrive in calm shallow waters. Similar palaeoecological interpretation for the depositional environment may be inferred for the Vitabäck Clays at Eriksdal.

The *Botryococcus* colonies of sample E:12, while also displaying excellent preservation, are found only at early stages of development, suggesting that the growth period or at least the growth conditions for these colonies were different, perhaps shorter, than those for sample E:5b.

The profuse number of colonies of *Botryococcus* found in

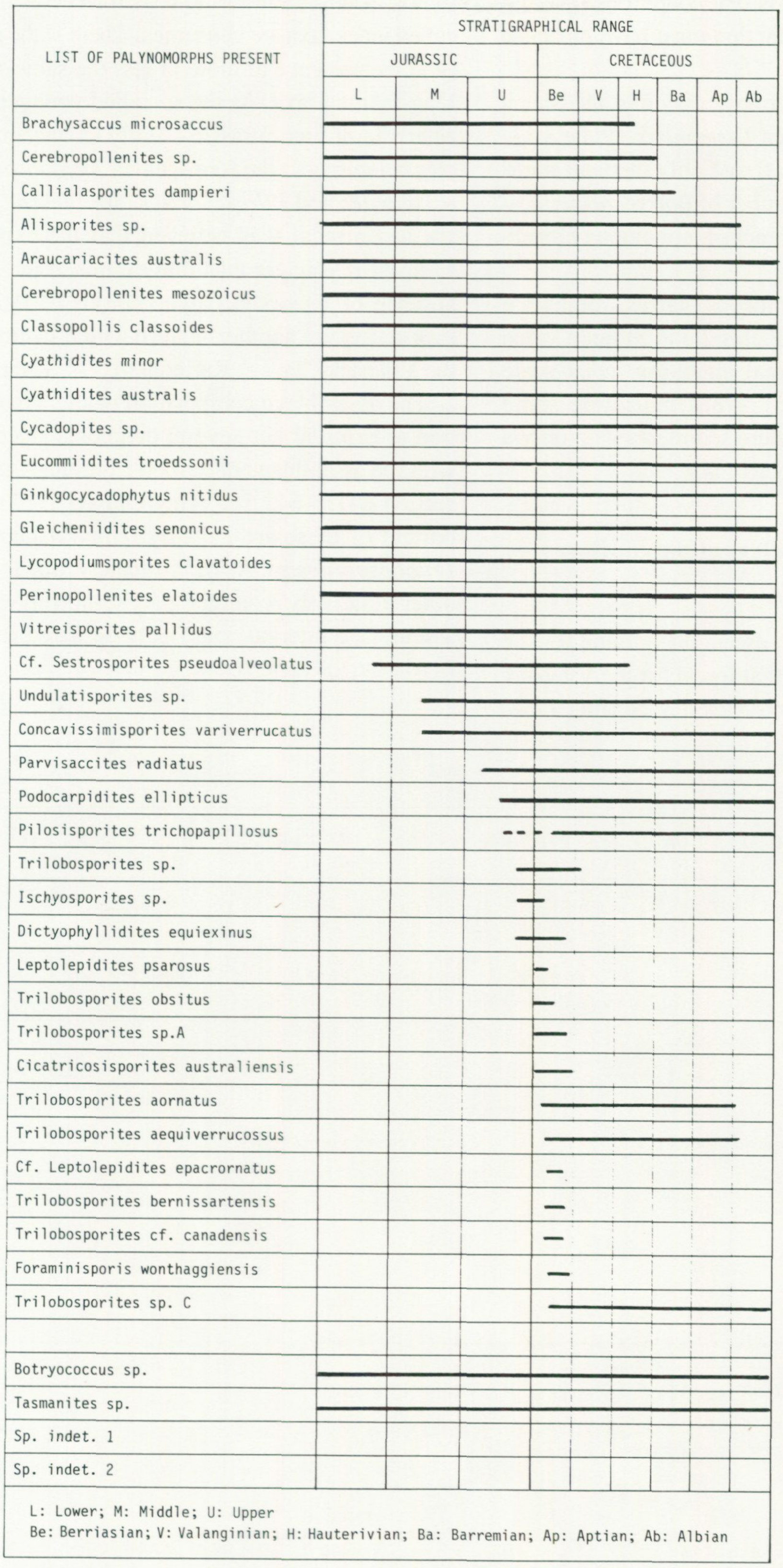

Fig. 24. Known published stratigraphical ranges of the palynomorphs found in the Vitabäck Clays. (Mainly after Norris, 1969; Herngreen et al., 1980 and Hunt, 1985).

samples E:5b, 12 and 35 suggests that conditions favourable to their existence and reproduction must have preceded their deposition.

The only indication of marine transgression is the occurrence of the green unicellular alga *Tasmanites* (Plate 3:13, 17 and 18) in sample E:12. It is found only in small numbers and together with a large number of *Botryococcus* colonies (Fig. 23) thus suggesting brackish conditions of sedimentary deposition.

The colour of the palynomorphs varies somewhat throughout the sample section (Plates 2 and 3) but a value of 3 was obtained on the thermal alteration index scale (T.A.I.) of Batten (1980, 1981, 1982) indicating some chemical change, marginally mature sediments with only a low hydrocarbon energy source potential.

Comparison with other relevant palynofloras

Sweden

Comparison of the palynomorph assemblage found for the Vitabäck Clays at Eriksdal with that found for the Vitabäck Clays (Zone C) of Karindal (Guy-Ohlson & Norling 1988) in NW Scania shows little resemblance as far as specific so called index taxa are concerned. There is the general similarity in the presence of more or less the same stratigraphically long-ranging taxa. As the so called younger elements characteristic of Late Jurassic – Early Cretaceous age, e.g. species belonging to the form-genera *Trilobosporites, Cicatricosisporites* and *Pilosisporites*, are present at Eriksdal and not at Karindal it is believed that the exposed section at Eriksdal is younger than that examined in NW Scania. The absence of reworked palynomorphs of Palaeozoic age at Eriksdal is yet another feature which distinguishes it from the Vitabäck Clays at Karindal in NW Scania.

The assemblage composition of the Vitabäck Clays section at Eriksdal has several diagnostic species in common with the assemblage described from the Kullemölla sample section 641.0–642.5 m (Guy-Ohlson 1982). The most important of these are *Pilosisporites trichopapillosus* and *Trilobosporites* sp. A. Unfortunately, due to the presence of other relatively younger palynomorphs this Kullemölla assemblage interval could only be dated rather broadly as Berriasian to Hauterivian.

TENTATIVE CORRELATION OF SELECTED PALYNOLOGICAL ASSEMBLAGES IN NW EUROPE

		ENGLAND		NETHERLANDS		SWEDEN	GERMANY
		Norris 1969, 1973	Hunt 1985	Burger 1966	Herngreen et al. 1980	Present work	Döring 1965
C	BERRIASIAN	C	*Matonisporites elegans*	X	*Cicatricosisporites-Plicatella*		G F E D C
				W			B
				V		Vitabäck Clays at Eriksdal	A
J	'PORTLANDIAN'	B	*Apiculatisporis verbitskayae*	U	*Classopollis*		b
		A	*Parvisaccites radiatus*				

Fig. 25. Tentative correlation of selected palynological assemblages in NW Europe (after Norris, 1969, 1973; Hunt, 1985; Burger, 1966; Herngreen et al., 1980 and Döring, 1965).

NW Europe

The palynoflora found in the Vitabäck Clays at Eriksdal has been compared with other NW European palynofloras of similar age in which the dominant constituents are pollen grains and spores. Perhaps the greatest similarity has been found with Britain where ever since the work of Couper (1958) there has been a great deal of interest and discussion about the palynomorph content (of the sediments at the junction of what is lithostratigraphically termed the Portland Stone Formation and the lower part of the Purbeck Formation) and the palynological criteria for the recognition, discrimination and correlation of the Jurassic–Cretaceous boundary in NW Europe (Norris 1969, 1973; Dörhöffer & Norris 1977; Batten in Thusu 1978; Hughes 1981; Wimbledon & Hunt 1983; Hunt & Wimbledon 1984; Hunt 1985; Batten et al. in Lord & Bown 1987).

Generally speaking, the assemblage composition of the Vitabäck Clays at Eriksdal compares favourably with that found by Norris for his suites B and C of southern England (1969, 1973) and for the Dutch assemblages found by Herngreen et al. (1980). Species which characterise both suites (Lower and Middle Purbeck Formations) are found except for the fact that *Classopollis* is a minor constituent of the Swedish assemblage whereas it is a dominant characteristic of all the assemblages of comparative age found in Britain. This would suggest a definite difference in facies. The Vitabäck Clays' palynoflora is dominated by palynomorphs of pteridophytic affinity. This predominance of a more drought intolerant group of plants suggests that more humid climatic conditions existed compared with that which must have existed for the *Classopollis* dominated assemblages in the upper part of the Portlandian Stone Formation and the lower part of the Purbeck Formation. The latter assemblages are thought to reflect a regional xerophytic vegetation (Hunt 1985).

Similar shifts from a *Classopollis* dominated palynoflora have been recorded elsewhere in NW Europe (The Netherlands and Germany) for sequences of comparable age (Hunt 1985). Increase in the number of *Botryococcus* colonies has also been recorded by Herngreen et al. (1980, text-fig. 4). A very tentative correlation of palynological assemblages in NW Europe is given in Fig. 25.

Other geographical regions

Comparison of the microflora found in the Vitabäck Clays at Eriksdal with microfloras from other geographical regions such as Canada (Pocock 1970), Argentina (Volkheimer & Quattroccio 1981) and Libya (Thusu et al. in El-Arnauti et al. 1988) shows that somewhat similar assemblage compositions are to be found, even if the similarity is more at the generic rather than at the species level.

Though many attempts have been made to correlate not only locally and within NW Europe but also over long distances (Schweitzer et al. 1987) the main factor hindering the reliability of such correlations is that the boundary stratotype for the Jurassic/Cretaceous has not yet been designated.

Depositional environment

Fyledal Clay (Oxfordian-Kimmeridgian)

The most conspicuous character of the Fyledal Clay is its uniformity. The individual beds in the clay dominated section are relatively uniform in composition. Apart from a few sandstone intervals the section is dominated by low energy deposition of fine-grained clastics, silt and clay. Changes are mainly found in colouration and occasional minor grain-size variations. The deposition therefore likely took place in an undisturbed quiet water environment.

The influx of coarse clastic material into the area was low which indicates a low hinterland relief and a protected position of the depositional area. The uniform composition of the Fyledal Clay in the region (cf. Ängelholm Trough and Landskrona area) indicates that there existed an extensive low relief, quiet water depositional environment over most of Scania. There is no evidence, however, that the sedimentation was synchronous in all places (Norling 1981).

Occurrence of rootlet beds, freshwater (lacustrine)-brackish-marine fossils (ostracodes, arenaceous foraminifers, calcareous algae, calcareous foraminifers), caliche nodules, gypsum and organic rich beds verifies deposition in shallow lakes, lagoons, and marshes (mangrooves) within a low relief coastal marginal environment, i.e. coastal plain (Fig. 26A). There were restricted marine influences during episodes of local subsidence and compaction of areas which subsequently were submerged. Shallow temporary brackish lagoons were developed in which mainly argillaceous sediments were deposited. Other marine influences are found as washover fan deposits of sand (Fig. 26A). During occasional high energy episodes, e.g. storms, the sea broke through the coastal barrier. Fan-shaped thin, generally less than 1 m thick, sheet-like deposits were laid down over the coastal plain. Marine origin is verified by detrital glauconite in these beds. The washover lobes scoured into the underlying sediments. Mudclasts and coarse debris therefore occur frequently in the lowermost part of the deposit. The basal gravel and coarse sand layers are laminated and often with shelly horizons. The upper parts are rippled and mainly composed of silt and fine-grained sand.

Shallow lakes constituted most likely an important element in the depositional setting. Anoxic bottom conditions in the quiet-water lakes yielded blackish organic rich clays and occasional shell debris accumulation. Carbonate nodules

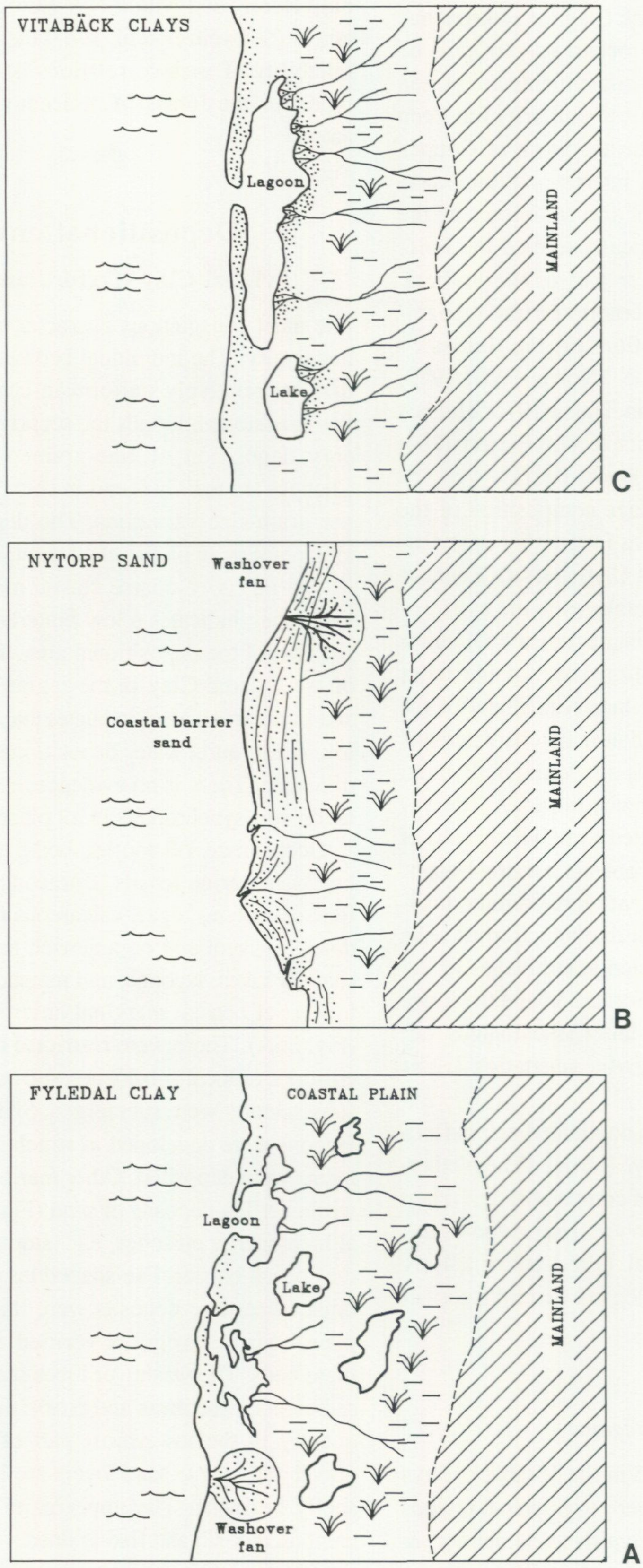

Fig. 26. Schematic reconstruction of the palaeodepositional environment during Oxfordian to Berriasian time in Scania. A: Fyledal Clay. Extended coastal plain environments with quiet water deposition in lagoons, lakes and wet marshes. B: Nytorp Sand. Coastal barrier and deltaic strand plains. C: Vitabäck Clays. Coastal plain dominated by lakes, lagoons and small rivers.

and gypsum in the upper part of the investigated section verify that the lakes were subject to evaporation which led to saturation and subsequent precipitation.

The intervening areas between the lakes and the lagoons consist of mainly wet marshes with deposition of clays and silts. Rootlet horizons in connection with blackish clays verify the occurrence of vegetated areas. Reddish Fe-oxyhydroxides and siderite in the section indicate occasional subaerial exposure and pedogenic processes.

The overall uniformity of the Fyledal Clay indicates a continuous subsidence of the depositional area which led to a preservation of a stable environment during much of the Oxfordian-Kimmeridgian time.

Nytorp Sand (Kimmeridgian-Portlandian)

The unit is not exposed in the area. Only geophysical indications and previous observations (Nilsson 1953) verify the presence of an approximately 20 m thick unit of sand (cf. Fig. 2A). Thus, the interpretation of the depositional environment is therefore based upon earlier investigations from drill-cores in the Ängelholm Trough, Landskrona area and in central parts of the Vomb Trough (Guy-Ohlson & Norling 1988; Norling 1987; Norling & Wikman 1990). The lithology indicates a coastal prograding sand barrier-strandplain-delta system (Fig. 26B). Findings of detrital coal, shell debris, and thin organic rich clayey beds interbedded in the whitish well sorted fine- and medium-grained sand verify an influence of back barrier coastal plain deposits, similar to the Fyledal Clay. Ferruginous and calcareous thin beds are also found, similar to the composition of the washover fan deposits in the Fyledal Clay.

The Nytorp Sand is interpreted as being formed as a result of decreased subsidence in the depositional area and increased exposure to waves and currents. Relative changes in sea-level and reworking led to partial destruction of the preceding extensive coastal plain environment (i.e. Fyledal Clay).

Vitabäck Clays (Portlandian-Berriasian)

The depositional environment of the Vitabäck Clays shows great similarities to that of the Fyledal Clay. The sediments, however, are more varied and slightly more influenced by coarse clastic material. The succession of strata and fossil content give a depositional environment dominated by conditions typical for marginal facies. Thus, the faunal and floral compositions all suggest a brackish-freshwater environment with some influences of marine conditions (Fig. 26C).

Lacustrine conditions are verified by palynomorphs (e.g. *Botryococcus*). Green and blackish organic-rich clays were deposited together with scattered silt-lenses during mostly quiet water conditions. Temporarily increased influence from small rivers is verified by infill sequences, e.g. the interval from E:1 to E:10 (Fig. 26C). The basal clayey beds in this sequence are interpreted as deposited during quiet water lacustrine or lagoonal conditions. Lagoonal or restricted brackish-marine influences are verified by bivalves in the underlying coquina bed (E:1; Ekström 1985). Increased supply of clastics (fine-grained sand) into the area, likely by rivers from the mainland, is verified by fine-grained sandy lithologies (e.g. E:5a). After the infill and subsequent closure of the lagoon followed a period of local subsidence and compaction. Depressions formed and shallow water lakes developed. Abundance of *Botryococcus* verifies a quiet water lacustrine depositional environment. In the upper part of this infill sequence (E:8-E:11) numerous plant fragments and poorly developed rootlet beds in connection with the organic rich blackish silty clays indicate deposition in a poorly drained marsh environment.

Occurrence of iron-rich interbeds and laminae indicates occasional subaerial exposure. Pedogenic processes are indicated by enrichment of trace elements (Mn, Co, Cu, Zn etc.) (cf. Jenkins 1985; Newman 1987; Chamley 1989). Gypsum was found by Nilsson (1953) over the same interval in adjacent localites. This may indicate, if the gysum is of non-diagenetic origin, that the lakes were of ephemeral nature and subject to dessiccation by evaporation. Increased amount of mixed layer clays (illite-smectite) over these intervals indicate further the presence of soil profiles in the section (cf. Robinson & Wright 1987; Deconick & Strasser 1987). Less well developed infill sequences and pedogenic processes are found in the upper part of the section (e.g. between 25 and 30 m).

Uniform sands found in the section are interpreted as proximal deltaic infill mouthbars and barrier sands. Typical washover fan deposits as in the Fyledal Clay have not been verified.

According to lithological descriptions it would appear that the Vitabäck Clays in the Ängelholm Trough, Landskrona area and Vomb Trough (Guy-Ohlson & Norling 1988; Norling 1970, 1972, 1981, 1982; Norling & Wikman 1990) were formed by similar depositional processes in extensive marginal coastal environments.

CONCLUSIONS

The ostracode fauna recorded in the Fyledal Clay at Eriksdal indicates a Kimmeridgian-Berriasian age. Samples prepared for palynological investigation were barren. In NW Scania, however, palynomorph stratigraphy as well as the foraminiferal fauna (Guy-Ohlson & Norling 1988; Norling 1972) give an Oxfordian-Kimmeridgian age for the Fyledal Clay.

The ostracode fauna recorded in the Vitabäck Clays at Eriksdal indicates a Portlandian – Berriasian age. From the known stratigraphical ranges of the palynomorphs it was possible to confirm a Late Jurassic – Early Cretaceous age for the examined sequence. The foraminiferal fauna recorded from the same member in NW Scania (Norling 1972; Guy-Ohlson & Norling 1988) indicates a similar age of Portlandian - Early Cretaceous age. The results of the palynological examination of the Vitabäck Clays at Eriksdal suggest that they also include even younger sediments than those of the same member in NW Scania.

The Fyledal Clay was deposited during a period when extensive coastal plains and marginal freshwater-brackish-marine environments dominated the palaeodepositional setting. The environment was stable as a result of continuous subsidence at the same rate as the infill process. Most of the sedimentation took place in lacustrine and restricted marine lagoons (brackish conditions). Dark organic argillaceous deposits formed in the partly anoxic shallow water lakes and lagoons. Intervening areas consisted of more or less wet marshes with deposition of silt and clay. Rootlet beds and pedogenic surfaces verify temporary subaerial exposure. Occasional dessiccation of shallow lakes resulted in deposition of carbonate nodular beds and precipitation of gypsum. Washover fan-like sheets of sands were occasionally deposited over the back barrier plain as a result of marine intrusion during e.g. storms.

The succeeding Nytorp Sand was mainly deposited as coastal sands in a barrier, deltaic and strandplain influenced system. Change in relative sea-level and increased exposure to waves and currents resulted in destruction and reworking of the preceding extensive coastal plain environment.

The Vitabäck Clays were formed in a depositional setting quite similar to the Fyledal Clay. Again, a coastal plain with lacustrine and lagoonal conditions dominated the environment together with poorly drained marshes. The varied conditions resulted in a composite deposition of clays, silts and sands. Dark organic clays were deposited in quiet water lagoons and lakes. Coarse clastics were deposited as mouth and sand barriers. Infill of lakes resulted in upward fining sequences topped by rootlet beds and pedogenic horizons. Occasional evaporation led to the precipitation of gypsum.

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APPENDIX

Alphabetical list of palynomorph species

Alisporites bilateralis Rouse 1959
Alisporites sp.
Apiculatisporites verbitskayae Dörhöfer 1979
Araucariacites australis Cookson 1947
Botryococcus sp.
Brachysaccus microsaccus (Couper) Mädler 1964
Callialasporites dampieri (Balme) Sukh Dev 1961
Cerebropollenites mesozoicus (Couper) Nilsson 1958
Cerebropollenites sp.
Cicatricosisporites australiensis (Cookson) Potonié 1956
Cicatricosisporites sp. B
Classopollis classoides (Pflug) Pocock et Jansonius 1961
Concavissimisporites variverrucatus (Couper) Brenner 1963
Converrucosisporites sp.
Coronatisporites valdensis (Couper) Dettmann 1963
Cyathidites australis Couper 1953
Cyathidites minor Couper 1953
Cycadopites sp.
Dictyophyllidites equiexinus (Couper) Dettmann 1963
Eucommiidites troedssonii Erdtman 1948
Foraminisporis wonthaggiensis (Cookson et Dettmann) Dettmann 1963
Gingkgocycadophytus nitidus (Balme) De Jersey 1962
Gleicheniidites senonicus Ross 1949
Inaperturopollenites dubius (Potonié et Venitz) Thomson et Pflug 1953
Inaperturopollenites sp.
Ischyosporites sp.
Leptolepidites epacrornatus Norris 1969
Leptolepidites clavatoides (Couper) Tralau 1968
Leptolepidites psarosus Norris 1969
Micrhystridium sp.
Parvisaccites radiatus Couper 1958
Perinopollenites elatoides Couper 1958
Pilasporites couperi Hunt 1985
Pilosisporites trichopapillosus (Thiegart) Delcourt et Sprumont 1955
Podocarpidites ellipticus Cookson 1947
Sestrosporites pseudoalveolatus (Couper) Dettmann 1963
Sp.indet.
Tasmanites sp.
Trilobosporites aequiverrucosus Dörhöfer 1977
Trilobosporites aornatus Döring 1964
Trilobosporites bernissartensis (Delcourt & Sprumont) Potonié 1956
Trilobosporites cf. *canadensis* Pocock
Trilobosporites sp. A
Trilobosporites sp. C
Trilobosporites sp.
Undulatisporites sp. (Cf. *Cibotium jurienensis* (Balme) Filatoff 1975)
Vitreisporites pallidus (Reissinger) Nilsson 1958

Plate 1

1. *Damonella* cf. *pygmaea* (Anderson, 1940)
   Vitabäck Clays, E:12. SEMx190

2. *Paracypris* ? sp.
   Vitabäck Clays, E:22. SEMx180

3. *Rhinocypris jurassica* (Martin, 1940)
   Fyledal Clay, EF:18. SEMx115

4. *Fabanella polita ornata* (Steghaus, 1953)
   Fyledal Clay, EF:18. SEMx80

5. *Scabriculocypris trapezoides* Anderson, 1940
   Fyledal Clay, EF:18. SEMx105

6. *Klieana alata* Martin, 1940
   Fyledal Clay, EF:18. SEMx120
   There is a wide variation within the paratypes, some of them lack reticulation and the wing-like processes are more or less distinct. The examined material falls within this variation. It does not possess extreme wing-like extension though it still has marked extensions on its ventral sides.

7. *Macrodentina transiens* (Jones, 1885)
   Vitabäck Clays, E:1. SEMx95

8. *Macrodentina (Polydentina)* cf. *rudis* Malz, 1958
   Fyledal Clay, EF:18. SEMx180

9. *Exophthalmocythere* sp.
   Fyledal Clay, EF:23. SEMx70

10. *Polycope* sp.
    Vitabäck Clays, E:12. SEMx160

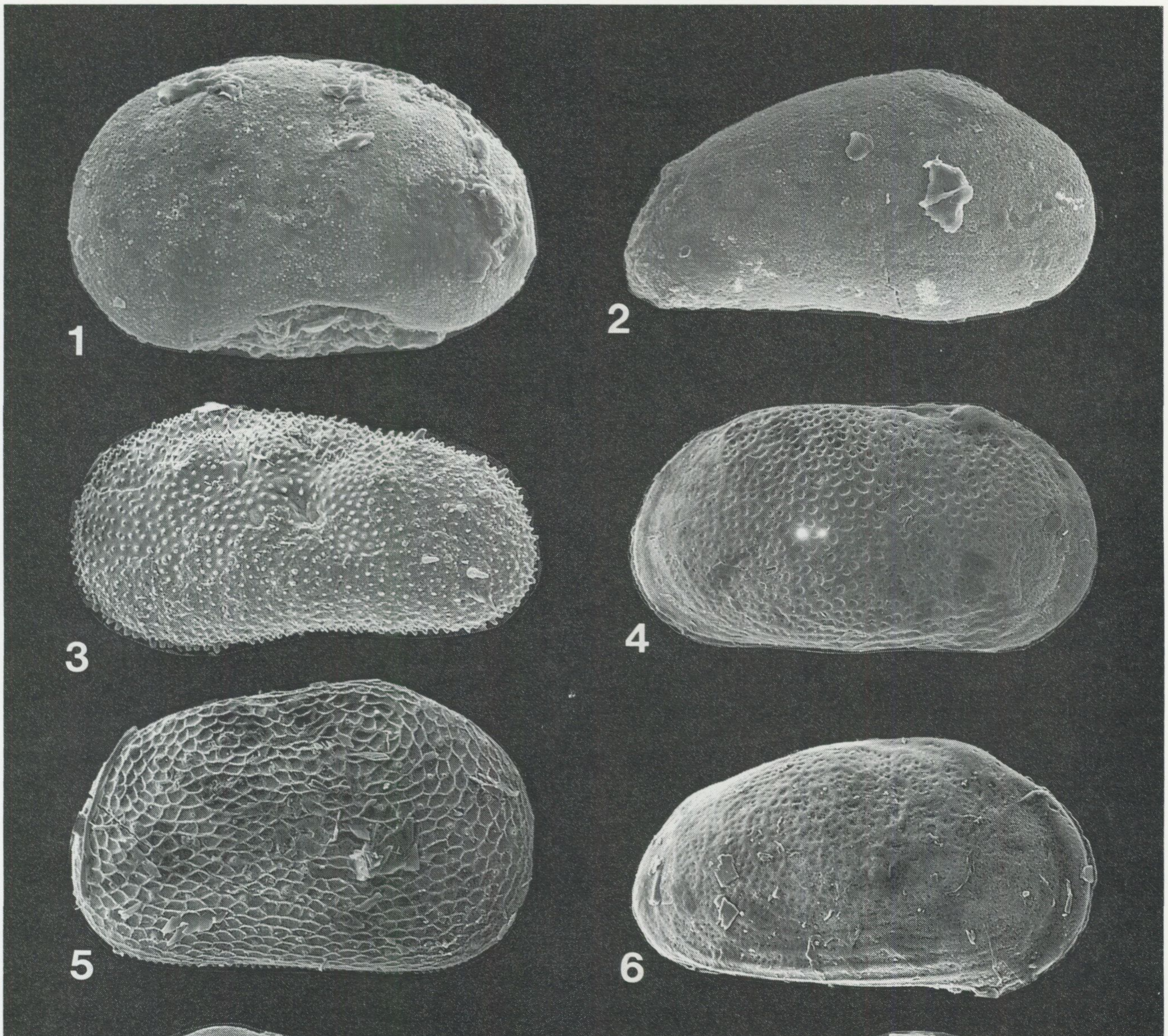
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Plate 2
(All photographs are at a magnification of x 1600)

1. *Dictyophyllidites equiexinus* (Couper) Dettmann
E:5b/1 (97.6/41.1)
2. *Cyathidites minor* Couper
E:28/1 (91.9/50.5)
3. *Gleicheniidites* sp.
E:28/1 (100.5/23.7)
4. *Gleicheniidites senonicus* Ross ?
E:5b/2 (101.5/29.1)
5. *Gleicheniidites senonicus* Ross
E:28/1 (11.9/22.6)
6. *Foraminisporis wonthaggiensis* (Cookson et Dettmann) Dettmann
E:35/1 (103.5/25.0)
7. Sp. indet.
E:5b/1 (113.6/ 29.3)
8. *Leptolepidites psarosus* Norris
E:9/2 (109.4/9.0)
9. *Trilobosporites* cf. *canadensis* Pocock
E:5b (112.4/48.0)
10. *Concavissimisporites variverrucatus* (Couper) Norris
E:5b/1 (106.8/38.1)
11. *Concavissimisporites* sp.
E:25/1 (110.6/34.1)
12. Cf. *Sestrosporites pseudoalveolatus* (Couper) Dettmann
E:25/2 (101.2/29.2)
13. *Pilosisporites* sp.
E:28/1 (96.7/40.4)
14. *Lycopodiumsporites clavatoides* (Couper) Tralau
E:28/2 (99.6/19.0)
15. *Pilosisporites trichopapillosis* (Thiegart) Delcourt et Sprumont
E:32/2 (99.4/38.3)
16. Cf. *Trilobosporites aornatus* Döring
E:25/2 (96.5/35.0)
17. *Trilobosporites bernissartensis* (Delcourt et Sprumont) Potonié
E:29/1 (105.8/22.6)
18. *Undulatisporites* sp.
E:28/1 (100.5/23.7)
19. *Trilobosporites aequiverrucossus* Dörhöfer
E:28/1 (91.9/ 50.5)
20. *Trilobosporites* sp. A
E:31/1 (95.2/22.2)
21. *Trilobosporites* sp. C
E:12/2 (98.4/31.7)
22. *Trilobosporites obsitus* Norris
E:12/2 (94.4/16.4)
23. *Cicatricosisporites* sp. B
E:35/1 (91.9/29.8)
24. *Cicatricosisporites australiensis* (Cookson) Potonié
E:12/4 (99.0/28.2).

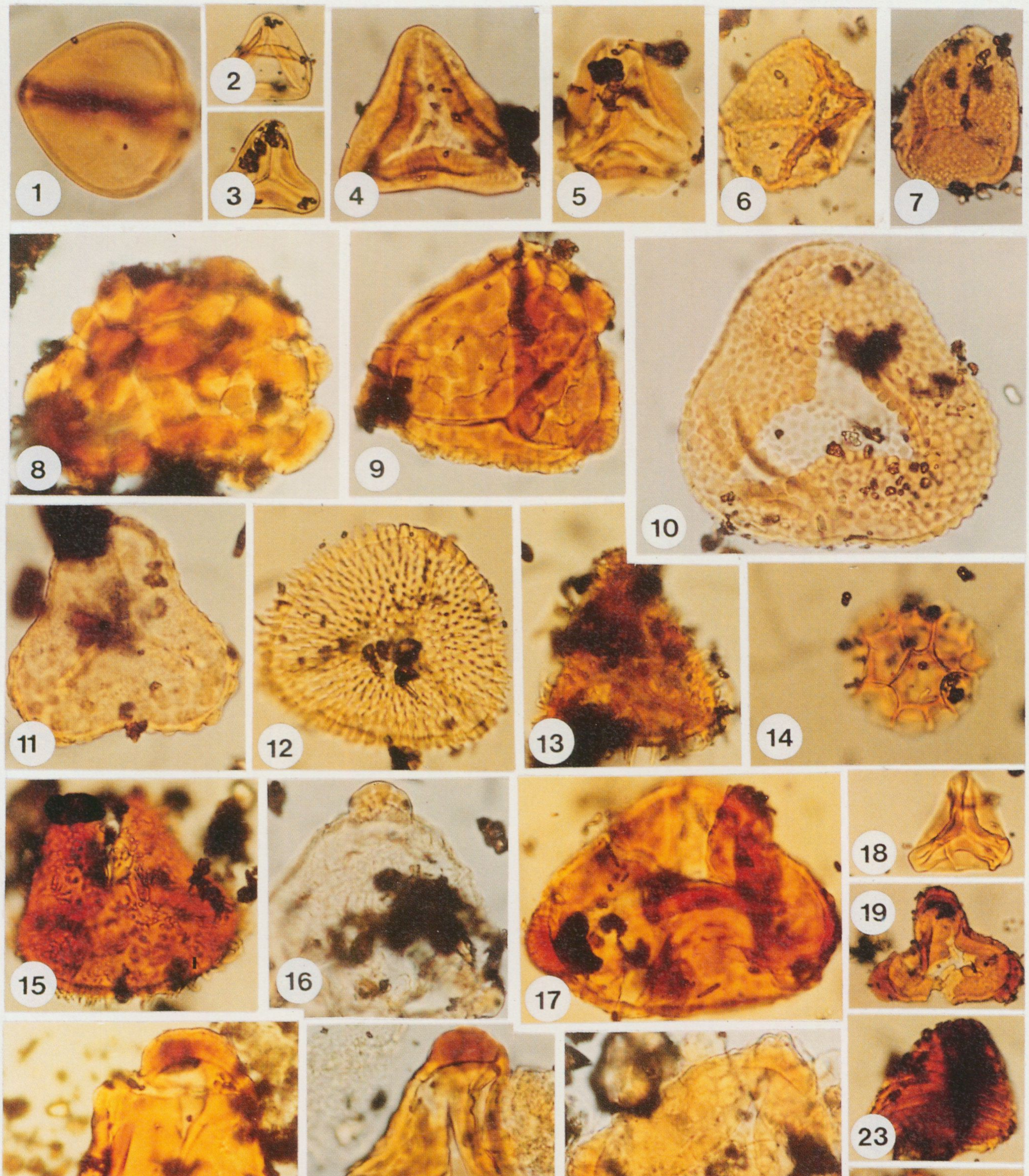
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Plate 3

(All photographs are at a magnification of x1600, except no. 18 which is x 400).

1. *Callialasporites dampieri* (Balme) Dev
   E:35/2 (109.8/39.8)
2. *Callialasporites dampieri* (Balme) Dev
   E:12/5 (105.0/24.6)
3. *Callialasporites dampieri* (Balme) Dev
   E:35/1 (91.7/36.2)
4. *Perinopollenites elatoides* Couper
   E 6/1 (90.0/27.4)
5. *Brachysaccus microsaccus* (Couper) Mädler
   E:6/2 (98.4/17.8)
7. *Alisporites bilateralis* Rouse
   E:28/2 (110.5/19.7)
8. *Parvisaccites radiatus* Couper
   E:3/2
9. *Parvisaccites radiatus* Couper
   E:35/2 (104.0/22.5)
10. *Podocarpidites* cf. *ellipticus* Couper
   E:5b/1 (101.6/27.2)
11. *Podocarpidites* cf. *ellipticus* Couper
   E:35/2 (104.0/22.5)
12. *Eucommiidites troedssonii* Erdtman
   E:28/1 (90.4/33.3)
13. *Cycadopites* sp.
   E:25/1 (112.6/35.5)
14. Sp. indet.
   E:19/3 (106.4/24.6)

15,17 *Tasmanites* sp.
   E:12/1 (112.8/48.5)

16. Cf. *Leptolepidites epacrornatus* Norris
   E:25/1 (105.2/45.0)
18. *Tasmanites* sp.
   E:12/6 (102.0/31.0).

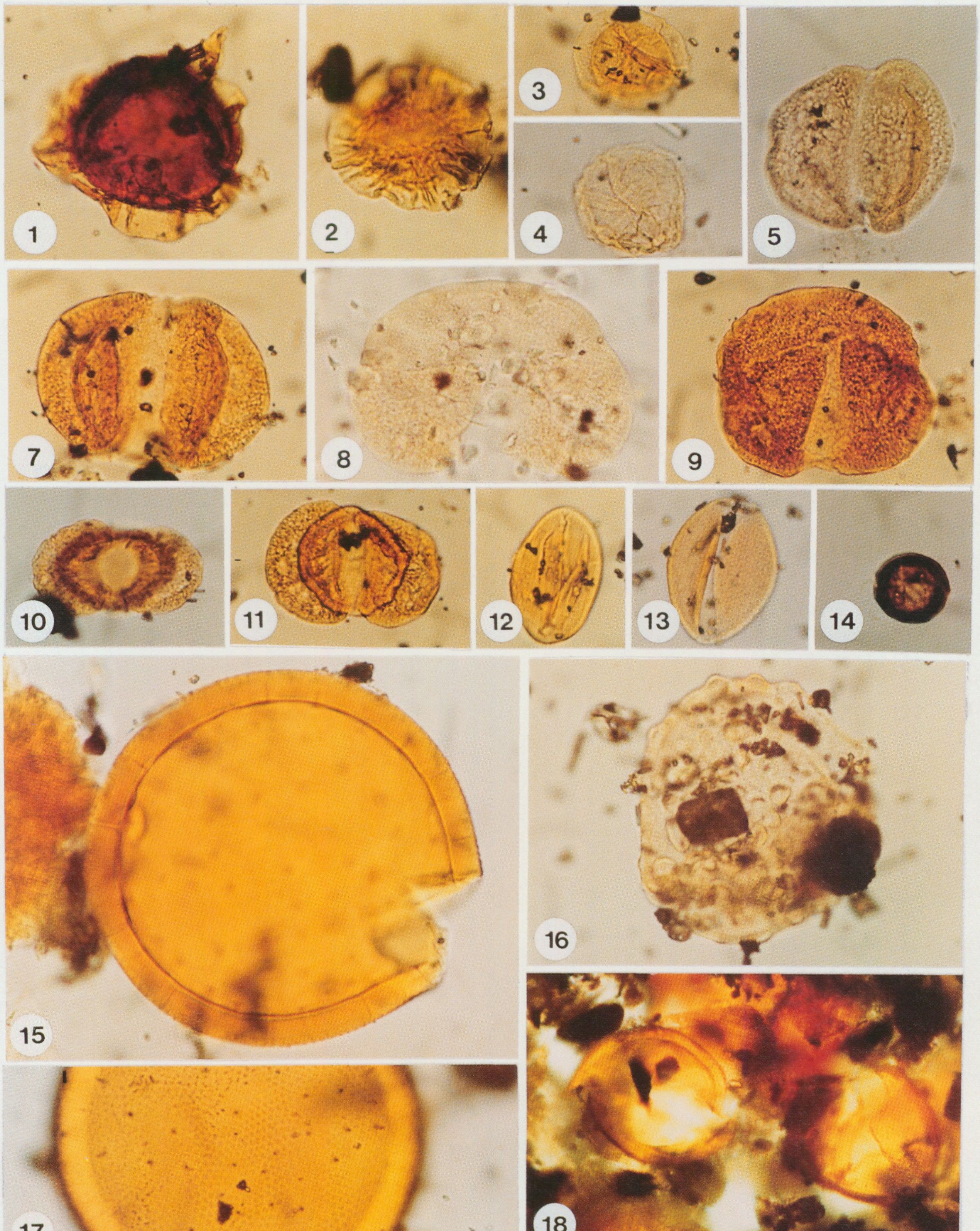
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Plate 4

(Bar line = 10 microns in all scanning electron micrographs except no. 18 where it is equal to 0.1mm)

1. *Cyathidites minor* Couper
   SEM-E:12 0228/25
2. *Cyathidites minor* Couper
   SEM-E:12 0225/25
3. *Gleicheniidites* sp.
   SEM-E:28 0286/31
4. *Gleicheniidites senonicus* Ross
   SEM-E:7 0229/26
5. *Trilobosporites* sp. B
   SEM-E:7 0269/30
6. *Converrucossisporites* sp.?
   SEM-E:12 0305/33
7. *Cerebropollenites mesozoicus* (Couper) Nilsson
   SEM-E:12 0227/25
8. *Pilosisporites trichopapillosus* (Thiegart) Delcourt et Sprumont
   SEM-E:12 0226/25
9. *Pilosisporites trichopapillosus* (Th.)Delcourt et Sprumont
   SEM-E:28 0251/28
10. Sp. indet.
    SEM-E:35 0257/28
11. *Apiculatisporites verbitskayde* Dörhöfer?
    SEM-E:35/2 0298/32
12. *Apiculatisporites verbitskayde* Dörhöfer?
    SEM-E:35/2 0298/32
13. *Ischyosporites* sp.
    SEM-E: 35/2 0296/32
14. *Coronatispora valdensis* (Couper) Dettmann
    SEM-E: 12/2 0276/30
15. Sp. indet.
    SEM-E: 19 0197/22

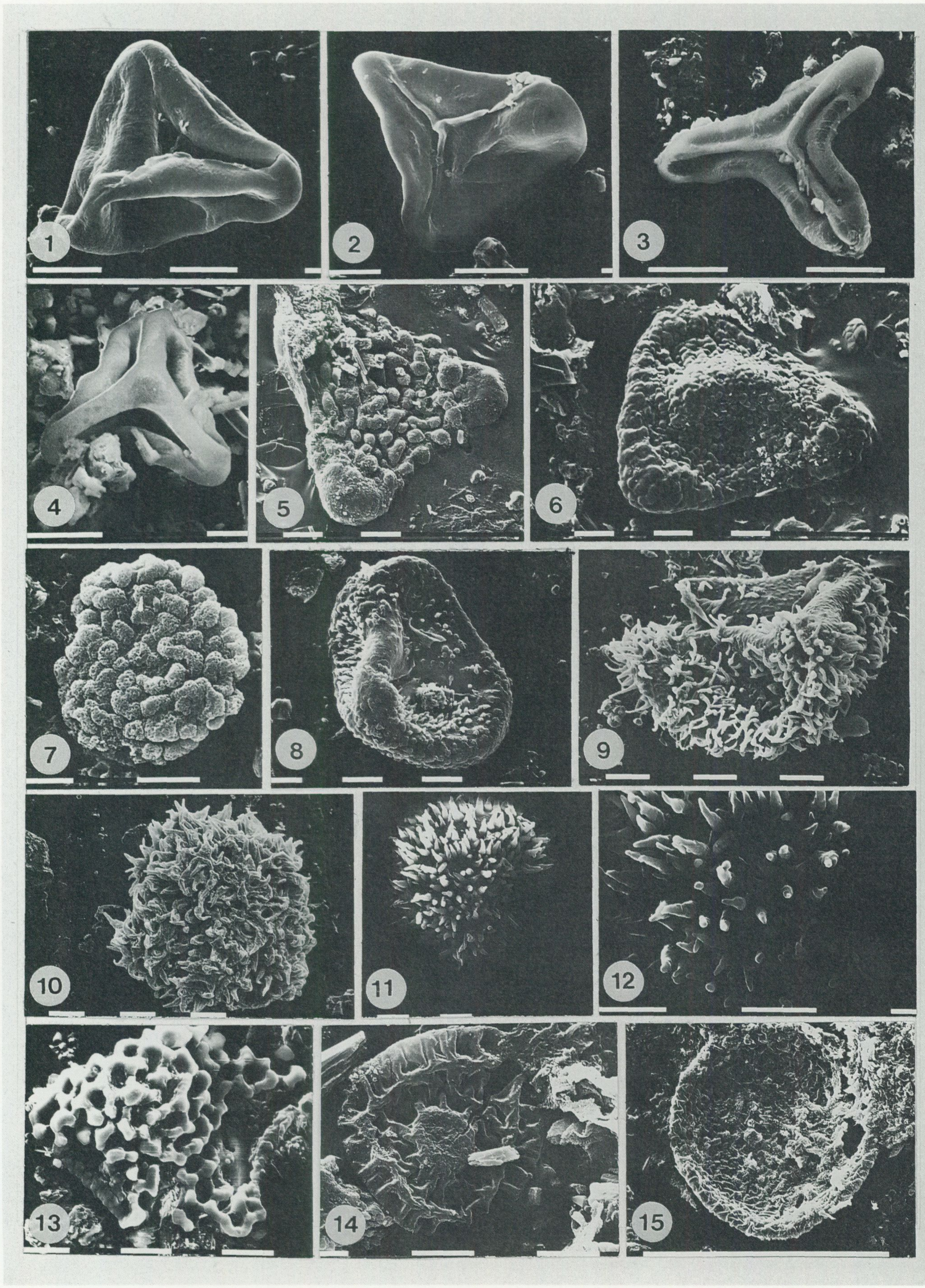
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Plate 5

(Bar line = 10 microns in all scanning micrographs except nos 13 & 14 where it equals 0.1mm)

1. *Cicatricosisporites australiensis* (Cookson) Potonié
   SEM-E:12 0219/24
2. *Cicatricosisporites australiensis* (Cookson) Potonié
   SEM-E:35/2 0300/32
3. *Cycadopites* sp.
   SEM-E:28 0245/27
4. *Ginkgocycadophytus nitidus* (Balme) De Jersey
   SEM-E:7/2 0271/30
5. *Inaperturopollenites dubius* (Potonié et Venitz)
   Thomson et Pflug
   SEM-E:25 042/27
6. *Inaperturopollenites* sp.
   SEM-E:25 0241/27
7. *Podocarpidites ellipticus* Cookson
   SEM-E:12 0215/24
8. Cf. *Podocarpidites ellipticus* Cookson
   SEM-E:5b 0235/26
9. Cf. *Parvisaccites radiatus* Couper
   SEM-E:7 0231/26
10. *Parvisaccites radiatus* Couper
    SEM-E:35 0255/28
11. *Alisporites bilateralis* Rouse
    SEM-E:7 0230/26
12. *Vireisporites pallidus* (Reissinger) Potonié
    SEM-E:28 0250/ 28
13. Plant fragments
    SEM-E:5b 0234/26
14. Plant fragments
    SEM-E:5b 0237/26.

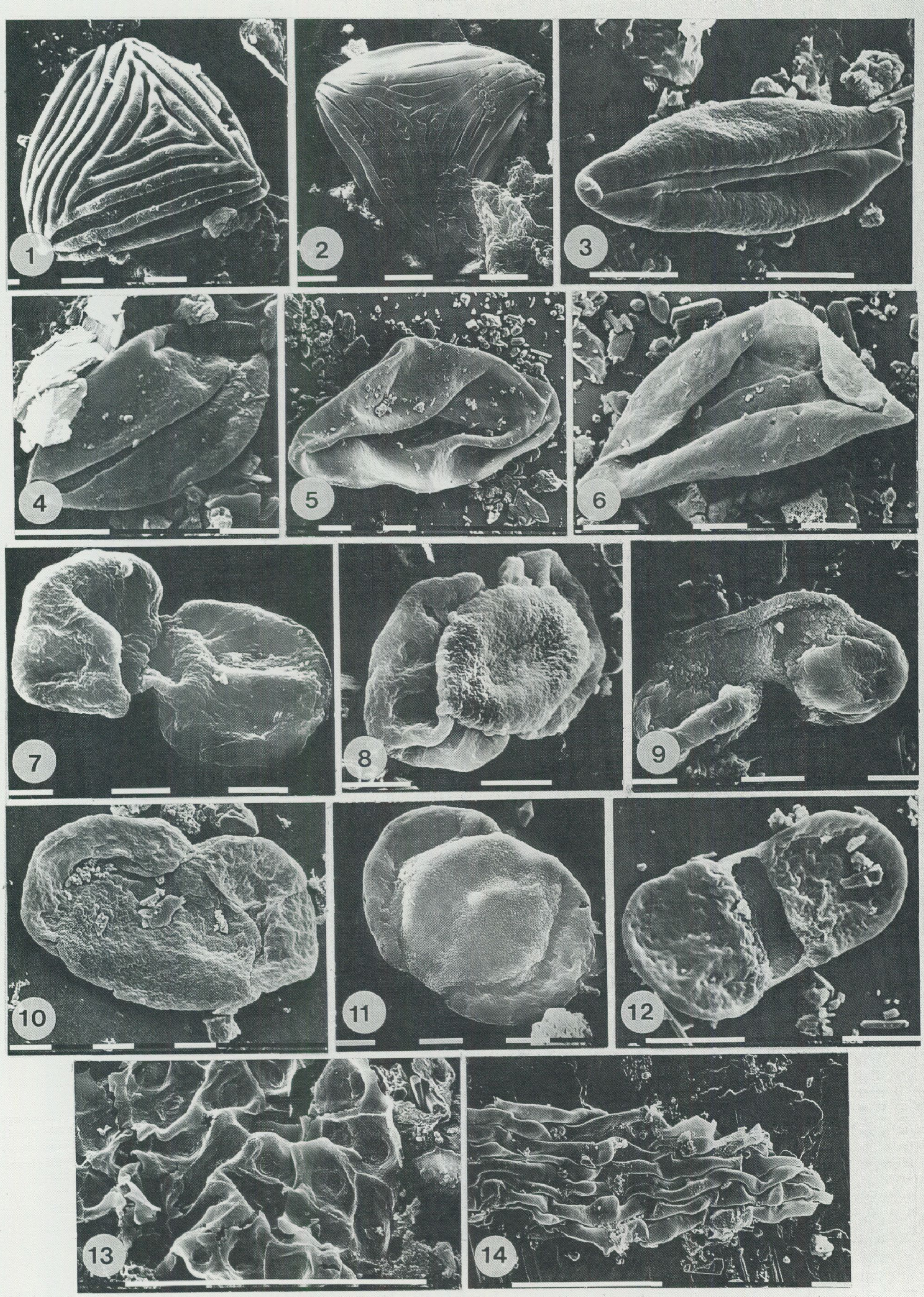
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Plate 6

(Bar line = 10 microns in all scanning electron micrographs except in no. 7 where it equals 0.1mm and in no. 13 where it equals 1.8 microns).

Different developmental stages of the colonial green alga *Botryococcus*.

1. Comparatively young colonies.
   SEM-E:12 0220/25
2. Successive daughter cups show division of the original mother cups.
   SEM-E:12 0223/25
3. Comparatively young colonies
   SEM-E:12 0216/24
4. Young compound colony
   SEM-E:12 0221/25
5. Arrows show several deformed cups
   SEM-E:5b 0267/29
6. Another morphological type of colony
   SEM-E:5b 0233/26
7. Comparatively young colony showing branched growth
   SEM-E:5b/2
8. Arrow indicating algal cell still present in mother cup
   SEM-E:5b/2 0266/29
9. Arrow shows successive "growth rings" of the previous cups
   SEM-E:5b/2 0265/29
10. Remains of base of cups
    SEM-5b/2 0263/29
11. Higher magnification of previous photo showing bases of original mother cups.
    SEM-E:5b/2 0264/29
12. Stalk of cup showing several generations of previous cups
    SEM-E:5b/2 0262/29
13. The bottom tip of each new cup can be seen inside the previos generation of cup - stacked rather like unused ice-cream cones.
    SEM-E:5b/2 0261/29.

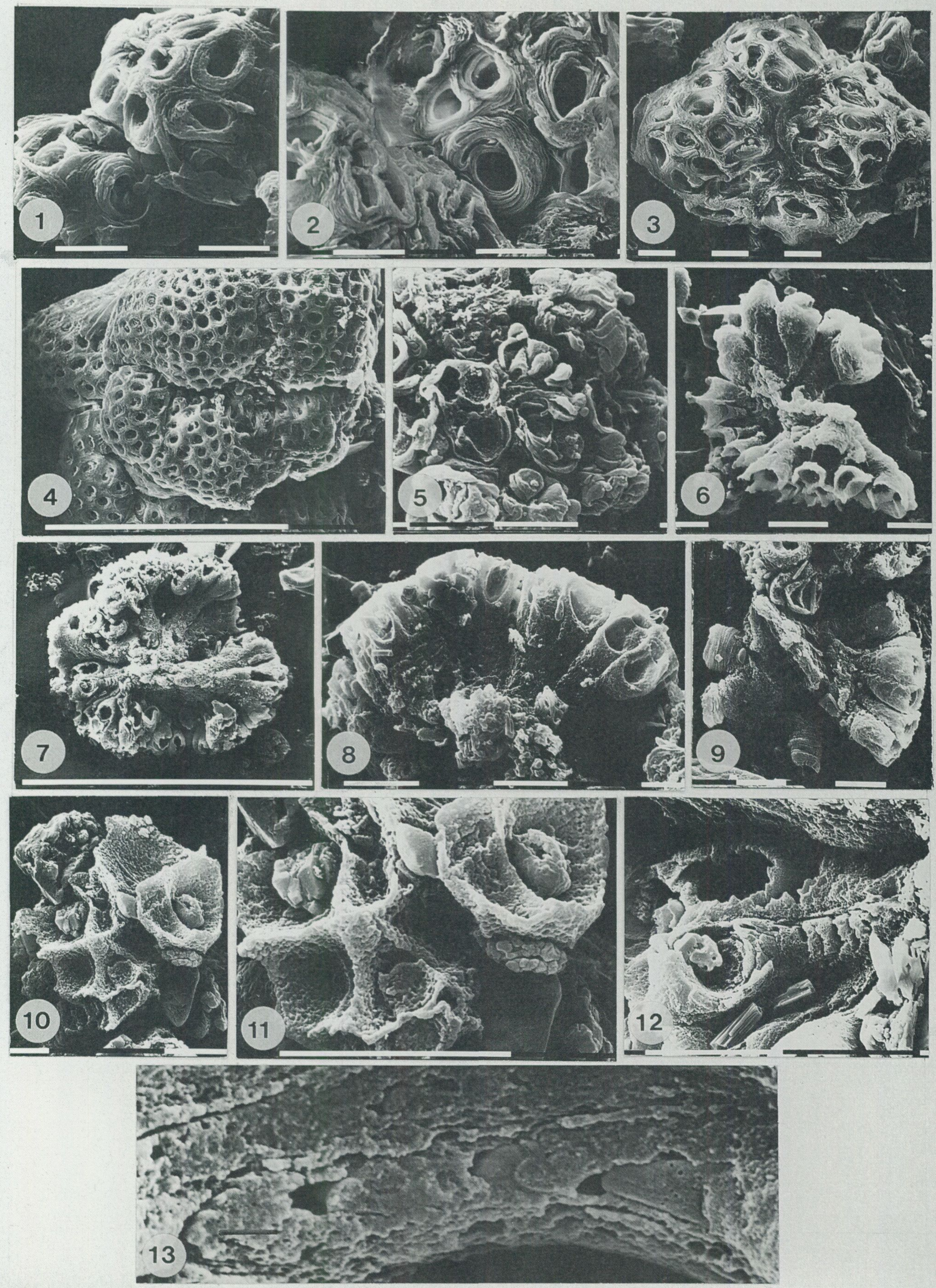
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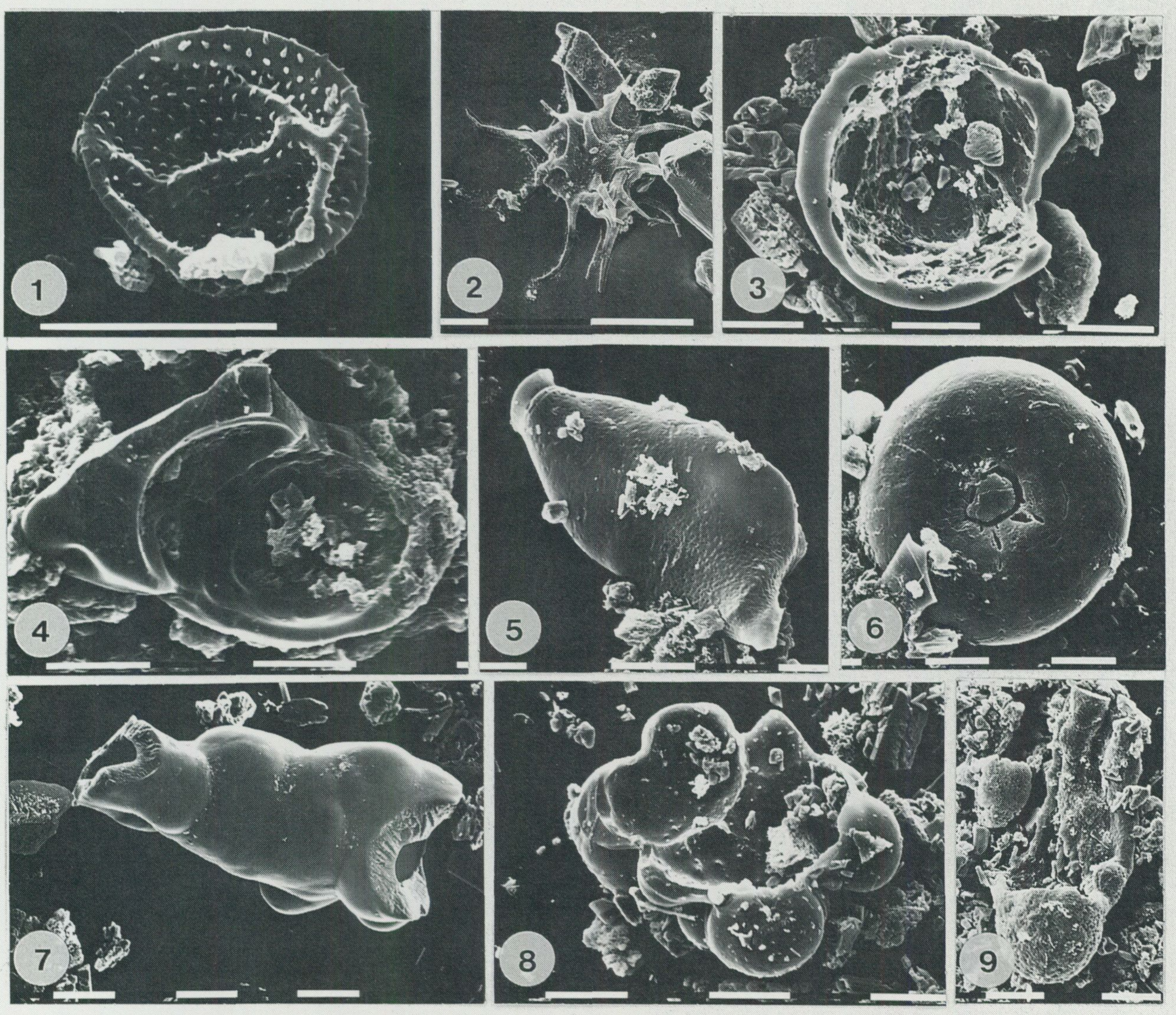
Plate 7
(Bar line = 10 microns in all scanning electron micrographs).

1. Acritarch. Sp. indet.
   SEM-E:12 0312/33
2. *Micrhystridium* sp.
   SEM-E:31 0252/28
3. Sp. indet.
   SEM-E:24 0240/27
4. Sp. indet.
   SEM-E:19 0188/22
5. Sp. indet.
   SEM-E:24 0209/24
6. Cf. *Pilasporites couperi* Hunt
   SEM-E:17 0200/23
7. Sp. indet.
   SEM-E:24 0239/27
8. Sp. indet.
   SEM-E:27 0243/27
9. Sp. indet.
   SEM-E:31 0253/28.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