DEVELOPMENT OF A LITORINA BAY AT EPOO, NEAR PORVOO, SOUTHERN FINLAND

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A sediment sequence at Epoo, municipality of Porvoo, on the South coast of Finland, altitude 25 m a.s.l., was studied for Holocene shoreline displacement in the Baltic Sea basin. The sediment sequence is made up of sand, clay-gyttja and drift peat deposited during the Ancylus and Litorina stages of the Baltic Sea. Two cores of clay-gyttja with an intervening sand layer were analysed for diatoms and pollen. The composition of the diatom flora changes from typical fresh-water species of the Ancylus Lake to brackish-water flora indicating transition to the Litorina Sea.

The sequence shows a gradual change of a group of separate islands in the Ancylus Lake to larger complexes of dry land because of uplift. As two necks of land were formed, the site developed into a sheltered brackish-water bay, and drift peat accumulated. A radiocarbon age of 6130 ± 50 yr BP obtained from the top of the drift peat links the shore with the Litorina regression. The shore displacement history of the Helsinki-Porvoo area is discussed.

Key words: changes of level, Ancylus Lake, Litorina Sea, sediments, diatom flora, pollen diagrams, Holocene, Epoo, Porvoo, Finland.

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Introduction

A sediment sequence with pre-Ancylus, Ancylus and Litorina sediments, mainly gyttja-clays and sands, was found in a gravel pit at Epoo, near the town of Porvoo, southern Finland (Fig. 1). Such deposits have usually been studied from ancient bay basins which are now mires or lakes. The Epoo site, however, never formed an isolated basin and therefore retardation of the shoreline is here determined by the altitude (25 m a.s.l.) and the age of the uppermost brackish-water sediment (drift peat).

The sediments at Epoo are exposed on dry land, which is rare in Finland and provides an exceptionally good opportunity to study the history of the Baltic Sea by analysing samples from a vertical section. This is particularly advantageous when thin beds, representing a short time span, are sampled for ^{14}C dating. It was also possible to take samples from under the sand layers.

Thanks to previous studies, shoreline displacement in the Porvoo area during the Litorina peri-

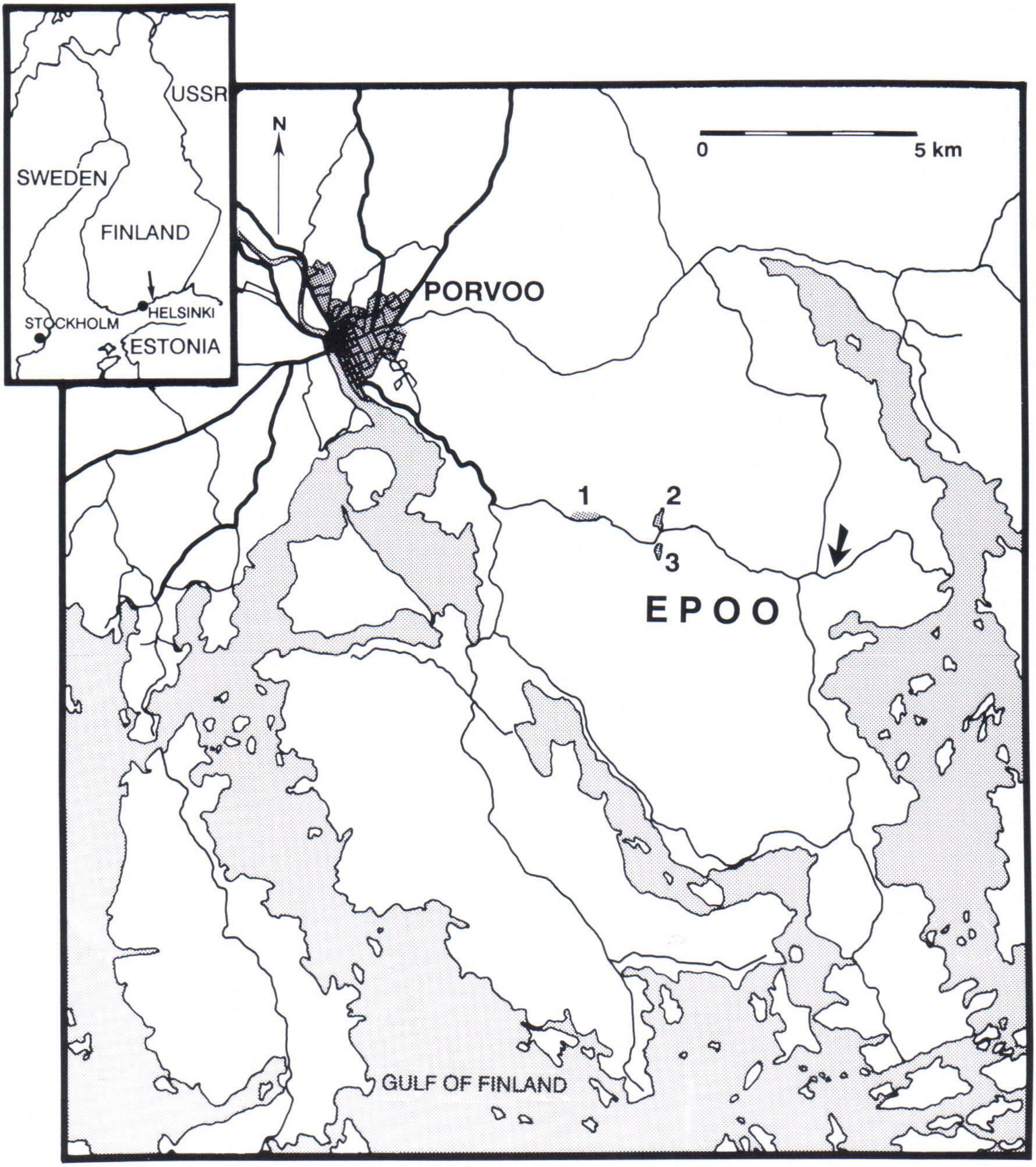

Fig. 1. The location of the study site at Epoo, municipality of Porvoo, southern Finland, some 50 km east of Helsinki. The study site is marked with an arrow. The numbers in the figure are the sites referred to in the text: 1 = Bastuberg Bog (Eronen 1974), 2 = Lake Gåsgårdsträsket, 3 = Lake Malmträsket.

od is relatively well known. Nevertheless some discrepancies have repeatedly been noticed when data on the Porvoo-Askola area and the neighbouring district in the west, Helsinki-Espoo, have been compared (Eronen 1974, 1983, Hyvärinen 1979, 1980). These inconsistencies are usually associated with the Litorina transgression. It is not out of the question that such deviations are due to the differential movement of large bedrock blocks during glacioisostatic uplift, a process that still continues. The occurrence of a transitional and slightly saline substage, the Mastogloia Sea, between the fresh-water Ancylus and the saline Litorina stages, has also been discussed (Hyvärinen 1984, Hyvärinen *et al.* 1988).

The gravel pit at Epoo is in an esker running from northwest to southeast. The pit was about to be destroyed by the removal of sediment for a local golf course. The »rescue sampling» operation was carried out in March 1990 by Matti Saarnisto and Raimo Kujansuu of the Geological Survey of Finland. The stratigraphical record in this paper is based on the photographs and notes of Matti Saarnisto.

Of the three authors, Uutela studied the diatoms, Sarmaja-Korjonen made the pollen analyses and Haila investigated shore displacement and palaeogeography.

Lithostratigraphy and laboratory techniques

The site is located at 60°20′57″N, 25°52′17″E and is at an altitude of 25 m a.s.l. Part of the exposed sediment wall collapsed during sampling. Core II was taken about 15 m away from Core I, as there was no difference in stratigraphy between these two sampling points. In the diagrams they are therefore presented as one. The lithostratigraphy (Fig. 2) was:

0—100 cm	sand (removed)
100—140 cm	clayey drift peat mixed with sand
140—160 cm	gyttja-clay with pieces of wood and macrofossils at about 150 cm
160—200 cm	sulphide stained gyttja-clay
200—235 cm	black sulphide gyttja-clay
235—260 cm	gyttja-clay, an alder log at 250 cm
260—280 cm	blue gyttja-clay
280—340 cm	sand
340—385 cm	gyttja-clay, at 385 cm mixed with sand
below 385 cm	glacial varved clay

The sediment succession at Epoo follows the general trend recognized in off-shore deposits of the Baltic Sea (Ignatius *et al.* 1981, Åker *et al.* 1988). Bottommost there are glacial varved clays. These are overlain by massive sulphide clays and these in turn by massive postglacial gyttja-clays. The intervening and covering sand layers that occur in the Epoo sequence are characteristic of a near shore depositional environment. The lithostratigraphy at Epoo and its relation to shoreline changes are discussed in the last chapter.

One cubic centimetre of sediment from every sampling depth was taken for diatom analysis. The organic matter was dispersed with hydrogen peroxide (H_2O_2) for at least 4 h at 50—60°C. The finer mineral matter was eliminated by discarding suspended clay before the coarse material was removed by decanting it 7—15 times (Battarbee 1986).

The diatom taxonomy used here follows that of Hustedt (1930), Mölder and Tynni (1967—1973) and Tynni (1975—1980). Five hundred unbroken diatoms were counted from each sample. The diatoms were grouped ecologically (Mölder 1943, Miller 1964) and are presented in Fig. 3:

— Brackish-water and fresh-water diatoms. Diatoms requiring saline water were absent.

— Planktonic and littoral diatoms. Littoral diatoms include epiphytic and benthic diatoms.

The samples for pollen analysis were first boiled in 10% potassium hydroxide (KOH) and afterwards sieved and decanted to remove any sand. Hydrofluoric acid (HF) treatment (Fægri & Iversen 1975) was needed because the residual material was mainly clay. The samples were mounted in glycerin. 500 arboreal pollen (AP) grains were counted from every sample.

For the loss-on-ignition determinations the

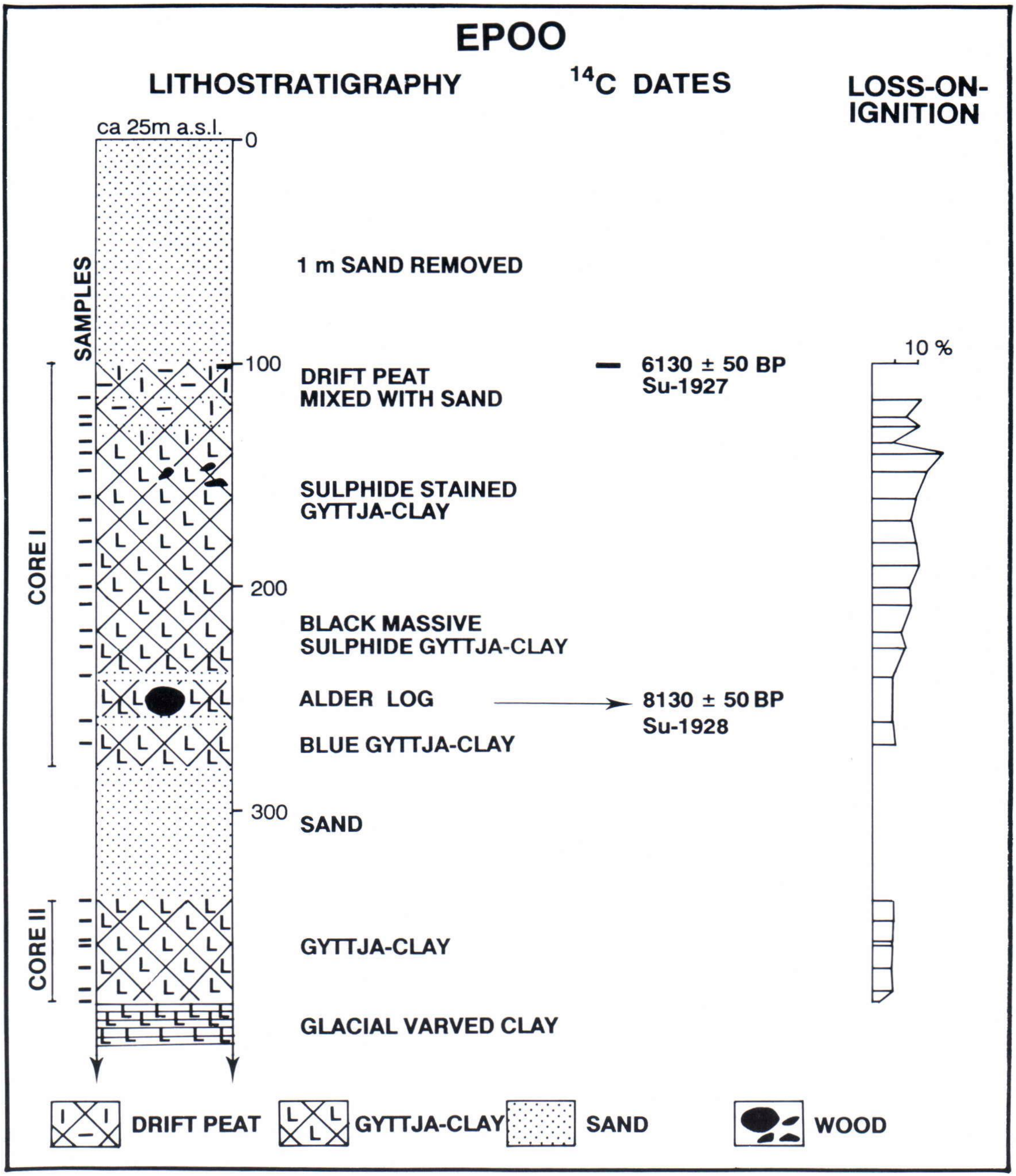

Fig. 2. Epoo, municipality of Porvoo, southern Finland. Lithostratigraphy, dates and loss-on-ignition curve.

samples were dried at 65°C over night and then heated at 550°C for 2 h.

Two radiocarbon determinations were made by the Radiocarbon Laboratory of the Geological Survey of Finland. See also Fig. 2.

The organic drift peat sample (Su-1927) was sieved; and the > 1 mm fraction was used for dating. It was subjected to acid-alkali-acid treatment to remove carbonate or humic contaminants. The wood (Su-1928) was dated from the 30 youngest annual rings. The sample was reduced to cellulose, because it yields the most reliable dates on wood.

The results are as follows (see also Fig. 3):

Organic drift peat at a depth of 100—101 cm, age 6130 ± 50 yr BP (Su-1927).

Alder wood at a depth of 250 cm, age 8130 ± 50 yr BP (Su-1928).

Microfossil record

Diatom Stratigraphy

Core II (385—340 cm)

The general character of the diatom flora succession of the Epoo section is shown in Fig. 4. At 385 cm, from where lowermost sample of Core II was taken, the diversity of diatoms was low, and many frustules were broken. The dominant species is *Melosira arenaria* (66.0%), which indicates sandy in-shore deposits. *Melosira islandica* + var. *helvetica, Diploneis domblittensis, Epithemia hyndmannii, E. turgida* and *Gyrosigma attenuatum* are also present. The composition is typical of Ancylus flora (Miller 1964, Eronen 1974, Alhonen *et al.* 1978, Ignatius & Tynni 1978, Eronen & Haila 1982).

The diatom flora becomes more heterogeneous upwards and the number of species increases. The proportion of *Melosira arenaria* decreases drastically from 19.6% (380 cm) to 4.2% (358 cm). *Gyrosigma attenuatum* and *Diploneis domblittensis* are common. *Epithemia hyndmannii* is also present as are *Opephora martyi* and *Stephanodiscus astraea*. All are species of Ancylus flora.

Over 96% of the diatom species indicate a fresh-water environment. Although planktonic species are abundant (max. 31.6% at a depth of 349 cm), littoral species form the dominant group. Thus the flora indicates the littoral facies of a large lake, *i.e.* the Ancylus Lake.

Core I (270—116 cm)

The diatom flora of the lower part of Core I again consists of the diatoms typical of a large fresh-water lake (the Ancylus flora). This flora is exceedingly rich, containing 109—141 different species. Up to 200 cm, *Melosira islandica* and *M. islandica* var. *helvetica* dominate, *Epithemia turgida* and *E. zebra* being almost as abundant. *Stephanodiscus astraea* and *Epithemia sorex* are also common. About half of the flora is planktonic.

Epithemia spp. dominates between 190 and 170 cm. At 190 cm there are many exceptionally asymmetric *Epithemia* frustules, suggesting that conditions were no longer ideal for *Epithemia* species. The proportion of *Melosira* specimens decreases, and *Stephanodiscus astraea* and *Epithemia sorex* are common. The flora becomes slightly more homogeneous, and 91 different species were recorded. To start with littoral species are dominant but they gradually diminish to 52.8%.

At 160 cm, there are maxima of *Fragilaria constricta* + *F. pinnata* (4.4%) and *Rhoicosphaenia curvata* (7.4%). The littoral species increase again until they constitute two-thirds of the flora, but only 56 taxa are present.

At 148 cm, *Epithemia* spp. is again dominant (80.6%). The species indicating brackish-water (e.g. *Diploneis smithii, Navicula peregrina* and *Rhabdonema arcuatum*) become slightly more abundant. *Mastogloia baltica, M. braunii* and *M. smithii* appear in minor quantities, probably indicating the beginning of the Mastogloia stage, which can usually only be identified in littoral facies (Eronen 1974, Ignatius *et al.* 1981). The littoral species constitute 94.2% of the flora. The number of taxa increases to 69.

At 140 cm, the proportion of brackish-water species suddenly rises to 31.8%, with a sharp maximum of *Mastogloia* spp. (20.0%). The other

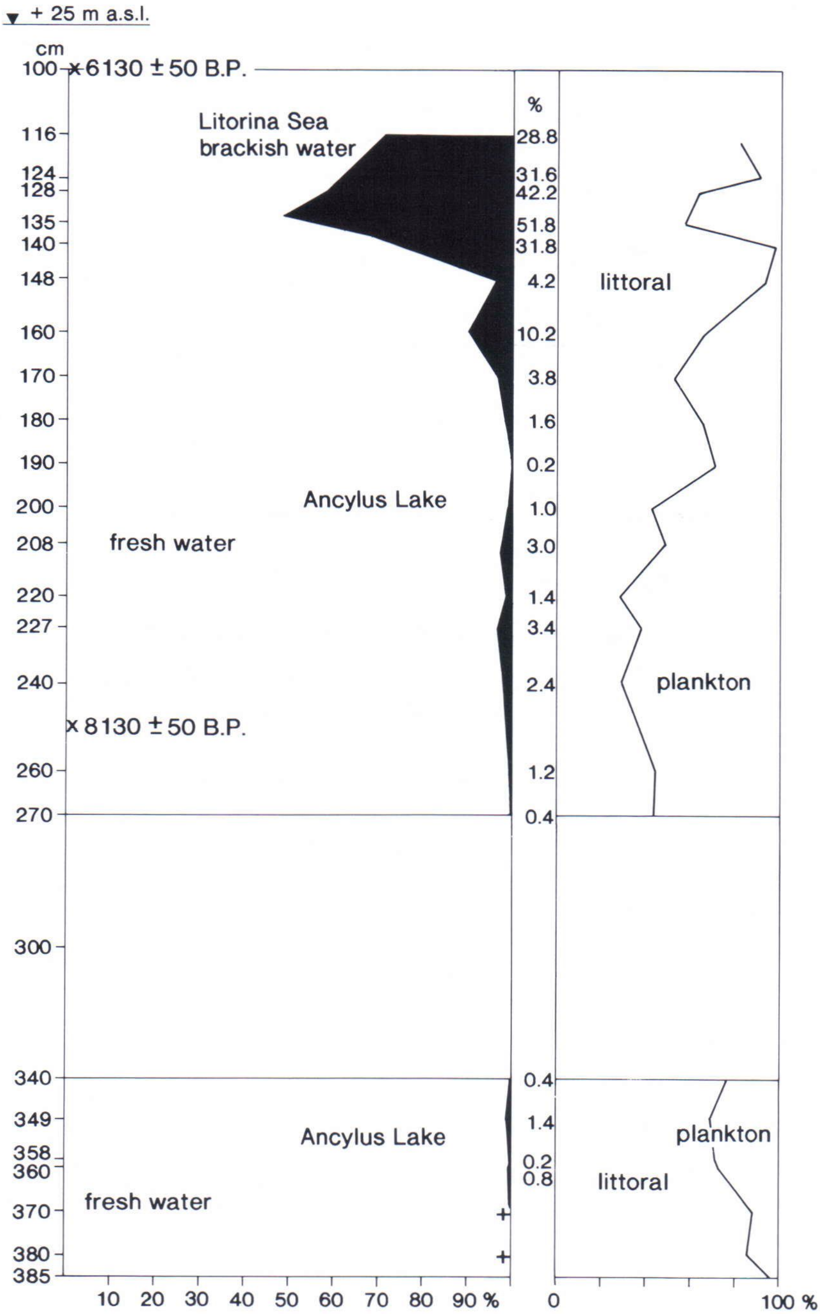

Fig. 3.. Epoo, municipality of Porvoo, southern Finland. Ecological assemblages of diatoms. Important fresh-water species are: *Melosira arenaria, M. islandica* + var. *helvetica, Epithemia hyndmannii, Gyrosigma attenuatum* and *Stephanodiscus astraea*. The main brackish-water species are mainly: *Melosira moniliformis, M. juergensi, Mastogloia braunii, M. elliptica* + var. *dansei, M. smithii, Campylodiscus clypeus, C. echeneis* and *Diploneis interrupta*. Species which live in a littoral environment are: *Melosira arenaria, M. juergensi, Epithemia* spp., *Gyrosigma attenuatum, Campylodiscus clypeus, C. echeneis, Diploneis interrupta* and *Mastogloia* spp. Planktonic species are: *Melosira islandica* + var. *helvetica, M. moniliformis* and *Stephanodiscus astraea*.

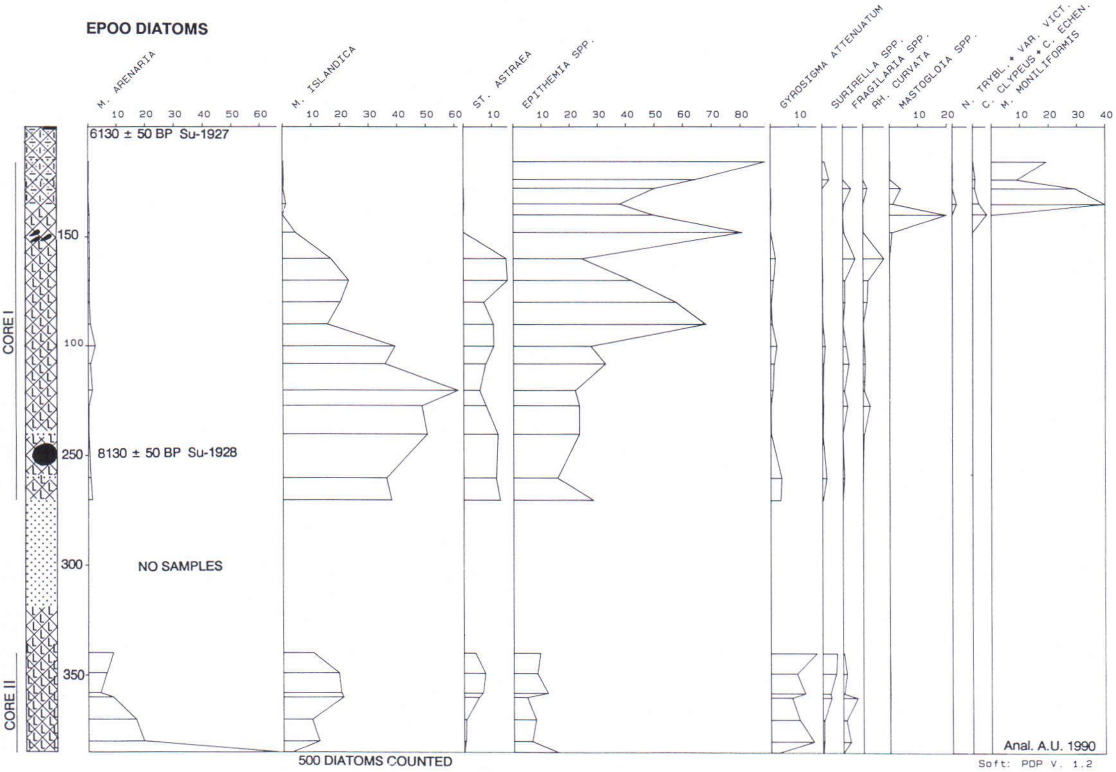

Fig. 4. Epoo, municipality of Porvoo, southern Finland. Relative diatom diagram. Only selected species are drawn. The Su-1928 date was determined from a log of alder found at 250 cm. The abbreviations of diatom families are : M. = *Melosira*, St. = *Stephanodiscus*, Rh. = *Rhoicosphaenia*, N. = *Nitzschia* and C. = *Campylodiscus*. Sediment symbols as in Fig. 2.

dominant species are *Epithemia turgida* and *E. sorex* (49.8%). At this level there is also a peak of *Campylodiscus clypeus* (3.0%) and *C. echeneis* (1.6%). Littoral species account for 99.4% of the flora.

At 135 cm, the brackish-water species are at their most abundant (51.8%), especially *Melosira moniliformis* (40.0%). *Melosira juergensi, Campylodiscus echeneis, Cocconeis scutellum, Mastogloia elliptica, Nitzschia tryblionella* var. *victoriae, Surirella striatula* and *Synedra tabulata* are also present. *Melosira islandica* and *Stephanodiscus astraea* disappear. About half of the flora belongs to the littoral facies of the brackish-water environment.

In the uppermost samples (128—116 cm) brackish-water flora make up 30%. The abundance of littoral species varies, but does not account for more than half of the flora.

Pollen stratigraphy

Core II (385—340 cm)

The pollen spectra of Core II (Fig. 5) are totally dominated by *Pinus*, which constitutes over 90% of AP in most of the samples. *Betula* is present, as are *Alnus, Corylus* and *Ulmus*, but the pollen grains of all of these, except *Betula* were corroded and faded. The non-arboreal pollen (NAP) flora consists of Poaceae, Chenopodiaceae and *Artemisia* along with Cyperaceae. Polypodiaceae spores abound.

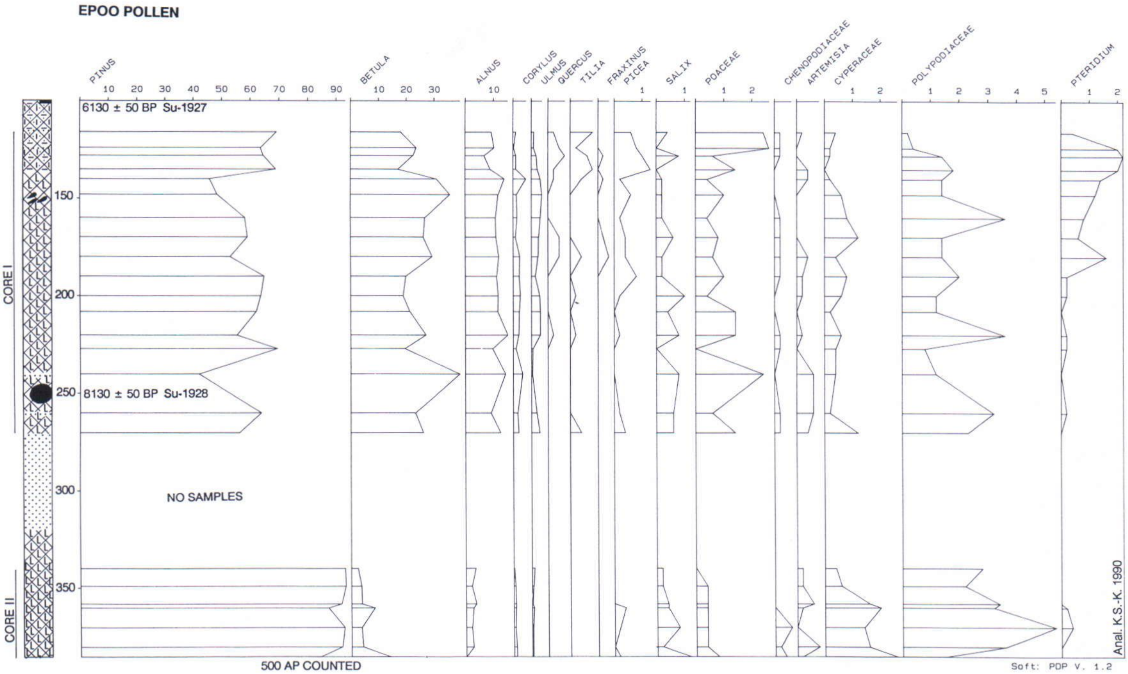

Fig. 5. Epoo, municipality of Porvoo, southern Finland. Relative pollen diagram. The Su-1928 date was determined from a log of alder found at 250 cm. Sediment symbols as in Fig. 2.

Core I (270—116 cm)

The dominance of *Pinus* continues, but not so totally, now reaching about 50—60%. *Betula* and *Alnus* pollen grains are abundant, the former with an abundance of about 20—30% and the latter with about 10%. The curves of *Corylus* and *Ulmus* are continuous, but *Quercus, Tilia* and *Fraxinus* are present more sporadically. The curve of *Tilia* becomes continuous at 140 cm. The NAP flora is about the same as in Core II. *Pteridium* spores increase towards the top, reaching 2% in the three topmost samples.

Conclusions

Core II

The diatom flora of Core II refers to a large lake, *i.e.* the Ancylus Lake. A shallow-water facies is indicated by the dominance of littoral species. The sand layer between Core I and Core II (Fig. 2) can also be attributed to decreasing water depth and wave washing. According to the pollen record, Core II represents the Pine Zone (V) of southern Finland (Donner 1971) with a total dominance of *Pinus* pollen. Most of the pollen grains of *Alnus*, and all of those of *Corylus* and *Ulmus* in these samples were corroded and faded and were presumably redeposited. The presence of an Ancylus Lake diatom flora and a *Pinus* pollen maximum together with insignificant *Alnus* values suggests that these spectra represent the time at about 9000—8500 yr BP.

Core I

According to the diatom stratigraphy, up to 140 cm, most of Core I consists of Ancylus sediments. The diatoms indicate a shallowing facies up to 140 cm, where the *Mastogloia* spp. appear, with a peak of 20%. This may allude to the

Mastogloia stage. The *Mastogloia* spp. are also known from fresh-water littoral environments close to carbonate sediments and limestone bedrock (Mölder & Tynni 1973), but none of these have been recorded from the Porvoo district (Laitala 1964).

At 135 cm, the abundance of brackish-water species is 51.8%, with a maximum of *Melosira moniliformis* and other brackish-water species indicating the beginning of the Litorina Sea phase.

The diatom stratigraphy of the Epoo sequence closely resembles that of Kvarnträsk in Espoo and of Lippajärvi in Vantaa (Hyvärinen 1984). After the fresh-water species of the Ancylus phase, there is a marked peak of *Mastogloia* spp. followed by the sudden appearance of the brackish to saline water species *Campylodiscus clypeus, C. echeneis* and *Melosira moniliformis*.

The maximum of *Campylodiscus* spp. (4.6%) remains insignificant compared with that at Bastuberg (Eronen 1974) near the Epoo site, at Gallträsket in Kauniainen (Alhonen 1972) or at Kuttulampi in Espoo (Hyvärinen 1982), where *Campylodiscus* accounts for 15—60% of the diatoms. The scarcity of this benthic lagoonal species at Epoo may be due to the exposure, which was more open than in the typical Clypeus lagoons mentioned above.

The pollen spectra of Core I can be placed biostratigraphically in the Birch-Alder-Hazel-Elm Zone (VI-VIII) (Donner 1971). The dominance of *Pinus* (50—60%) is atypical of small lake sediment records and must reflect the sedimentary environment, *i.e.* a littoral environment in which waves gathered floating masses of *Pinus* pollen.

The spread of *Alnus* is not seen in the diagram, as Core II and I are separated by a sand layer from which no samples were taken. The processes forming the sand layer may also have eroded the topmost sediments of Core II. At the beginning of the upper part (Core I) of the diagram, *Alnus* is already present as an established constituent of the vegetation, with its pollen amounting to about 10%. The date of a piece of alder log from 250 cm, 8130 ± 50 yr BP (Su-1928), also shows that *Alnus* was present in the Porvoo district at this time.

There are two ways to explain the *Tilia* curve, which seems to be the key to the dating of the upper part of the pollen diagram. First, a sea coast is an unsteady depositional environment, and pollen sedimentation and transport are controlled by the depth of the water and the distance from forests. Therefore the spread of *Tilia* to the Porvoo district could be seen as an echo at 200 cm, the depth at which the first well preserved *Tilia* pollen grain was found. Eronen (1974, p. 134) has reported a date of 7250 ± 250 yr BP for *Tilia*° (the beginning of the continuous *Tilia* curve) from Bastuberg, some five kilometres west of the Epoo site (see also Aartolahti 1967 and Tolonen & Ruuhijärvi 1976).

However, the fact that most previous studies from the Espoo-Helsinki-Porvoo area (*e.g.* Alhonen 1972, Eronen 1974, Hyvärinen 1984) have a clear *Tilia*° horizon analysed from similar material, *i.e.* gyttja-clay and clay-gyttja, from environments just as unsteady as that at Epoo, renders this explanation questionable.

The second and the most likely alternative is that the *Tilia*° horizon should be placed at 140 cm, where the *Tilia* curve becomes continuous. The *Tilia*° horizon is most probably not synchronous on the south coast of Finland (Tolonen & Ruuhijärvi 1976). It also depends on the methods of pollen analysis used, *i.e.* the number of pollen grains counted, the interval between the samples analysed and the edaphic characteristics of the area. It is often contemporary with the appearance of the brackish-water diatom species of the Litorina stage at about 7500—7200 yr BP. In the Epoo sequence the Litorina diatom flora appears at 140 cm (Fig. 4).

Sedimentation must have been rather rapid between 270 and 140 cm (Core I) which thus covers the time span of about 8200—7200 yr BP. Deposition of only 40 cm of sediments between 7200 and 6100 yr BP seems improbable and suggests that there is a hiatus near the top of the sediment sequence. The sand layers in the drift peat also point to unsteady sedimentation conditions and to the possibility that a gap exists between the organic surface (about 6100 yr BP) and the *Tilia*° horizon (about 7200 yr BP).

The Litorina transgression in the Porvoo, Helsinki and Stockholm areas

The data on the Epoo sequence are in good agreement with the general concept of the shore displacement for the Porvoo area. The relative chronology there has earlier been studied by *e.g.* Hyyppä (1937), Virkkala (1953), Sauramo (1958), Tynni (1960, 1966). The interpretations rely on pollen and diatom analyses and on shoreline data. Diagrams with absolute dates have been published by Hyyppä *et al.* (1962) Tynni (1966), Eronen (1974) and Matiskainen (1989a).

A Litorina site often referred to, and only about 5 km west of the present study area, is the Bastuberg bog (Fig 1), which has been studied by Eronen (1974; see also Hyyppä *et al.* 1969). It forms the basis for the shoreline displacement curves constructed for the Porvoo area (Eronen 1974, 1983; see also Eronen 1976 and Matiskainen 1989b). The basin was almost isolated at 8480 ± 190 yr BP (Hel-394) and the flooding waters of the Litorina transgression reached its threshold (28.5 m a.s.l.) at about 7250 ± 240 yr BP (Hel-392). The final isolation occurred at around 6230 ± 220 yr BP (Hel-391). The diatom stratigraphy supports the chronology.

The two small lake basins also marked on the map (Fig. 1) have a threshold altitude a couple of metres lower than that of the Bastuberg bog (Lake Gåsgårdsträsket 25 m a.s.l. and Lake Malmträsket 22.7 m a.s.l.). No unequivocal evidence for isolation before the onset of the Litorina transgression has been found (Eronen 1983). The radiocarbon-dated isolation contacts of these neighbouring basins clearly indicate that the regressive sea level was at about 24 m a.s.l. 5600—5700 ^{14}C years ago.

Detailed research on the Litorina transgression in the Helsinki region has been carried out in recent years by Hyvärinen (1979, 1980, 1982, 1984; see also Hyvärinen & Eronen 1979 and Hyvärinen *et al.* 1988). According to him, the Litorina stage began soon after 7500 yr BP and the peak of the transgression was reached at about 7000 yr BP. He states further that the transgression can be distinguished only in the area east of Helsinki or in the area with isobases lower than 3 mm for the present annual uplift (the assumed eustatic rise of 0.8 mm yr^{-1} is included).

Findings at variance with this conclusion have been published by Hyyppä (1937, 1950), Eronen (1974) and Alhonen *et al.* (1978). In the vicinity of Askola, a municipality about 25 km northwest of Porvoo, a Litorina transgression with an amplitude of a couple of metres has been reported on isobases higher than 3 mm/a (refers to the Litorina shore at about 30—32 m a.s.l.) (Virkkala 1953, Tynni 1966).

Matiskainen (1989b) restudied some of the basins in the Askola region but could not recognize any clear Litorina transgression extending above 32 m a.s.l. Ristaniemi and Glückert (1988) have traced and dated the Litorina transgression in Bastukärr bog, southwestern Finland, at an altitude of about 38 m a.s.l.

These conflicting interpretations may be due to the fact that during a period of nearly stagnant shore line even small local deviations from a regular uplift pattern may produce signs of transgression (Eronen 1974, Nuñez 1978, Hyvärinen 1979). A contemporaneous change from fresh to brackish water conditions causes a drastic change in the diatom flora, which may further confuse interpretations. Temporary high water levels caused by storms and events such as threshold erosion also result in changes in the littoral and lagoonal sedimentation facies (Hyvärinen 1980, 1984).

A preliminary shoreline displacement curve constructed for the Stockholm region by Miller (in Brunnberg *et al.* 1985) shows a double-peaked Litorina transgression reaching over 50 m a.s.l. with an amplitude of several metres. In a shoreline displacement curve by Risberg (1991) the

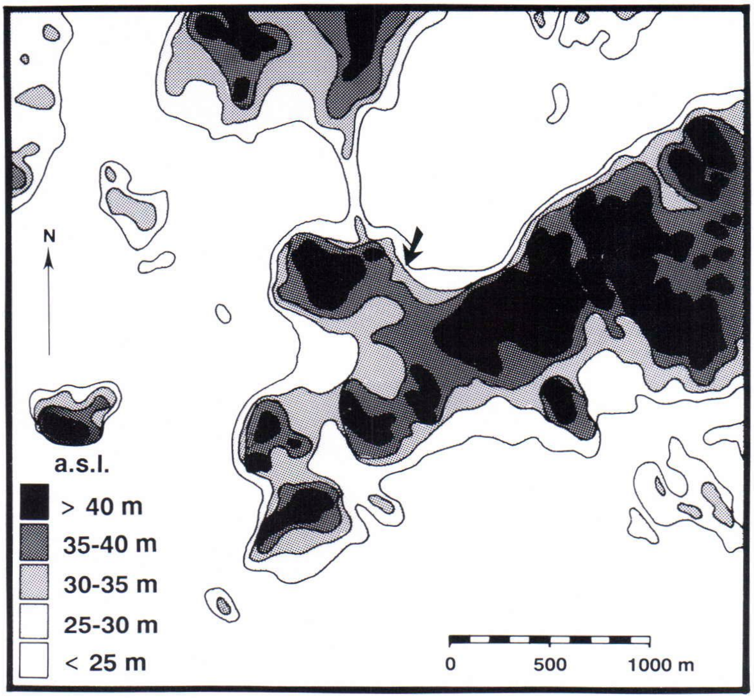

Fig. 6. Epoo, municipality of Porvoo, southern Finland. Palaeogeographical map showing the zones of different altitudes. The zones can be linked with the shore displacement of the area and the development of the study site from an archipelago to a sheltered bay. The study site is marked with an arrow.

highest Litorina level in the same area comes close to 60 m a.s.l. after a transgression of about 7 m.

If the discrepancy in the appearance of a transgressive Litorina Sea in southern Finland and in the Stockholm region is not merely due to misinterpretation of the stratigraphical record, a clear change in the uplift pattern since the early Litorina Sea stage seems plausible.

Shoreline changes at Epoo

Shoreline displacement at Epoo (Fig. 7) during the Yoldia and Ancylus stages can only be approximated, using data collected from basins at higher altitudes in the neighbouring regions (*e.g.* Hyyppä 1937, 1950, Sauramo 1954, 1958, Mölder *et al.* 1957, Valovirta 1965, Tynni 1966, Donner 1980, Donner & Eronen 1981, Eronen & Haila 1982, Ristaniemi & Glückert 1987, Matiskainen 1989b).

The Yoldia regression was rapid, lowering the water level at Epoo from about 75 to 40 metres a.s.l. between 10 200 and 9600 yr BP. By about 9300 yr BP the shoreline then had risen by about 10 m as a consequence of the Ancylus transgression, reaching a level of 50 m a.s.l. The Ancylus regression, following the culmination of the transgression, started vigorously, slowing down at about 8500 yr BP, when the water level had fallen to some 30 m a.s.l.. In time, this corresponds to the start of the ingression of oceanic water into the Baltic basin, first into Mecklenburg Bay. The Mastogloia transgression started between 8500 and 8000 yr BP in the southern Baltic Sea (*e.g.* Eronen *et al.* 1990).

At Epoo the sea water level may have stagnated or turned into a slow transgression towards the end of that period. No clear proof of this early rise in sea level in southern Finland has been reported. At Epoo the shore level was most likely between 30 and 25 m a.s.l. from 8000 to 6000 yr BP. The peak of the Litorina transgression, which reached an altitude of about 28 m a.s.l., took place at around 7000 yr BP.

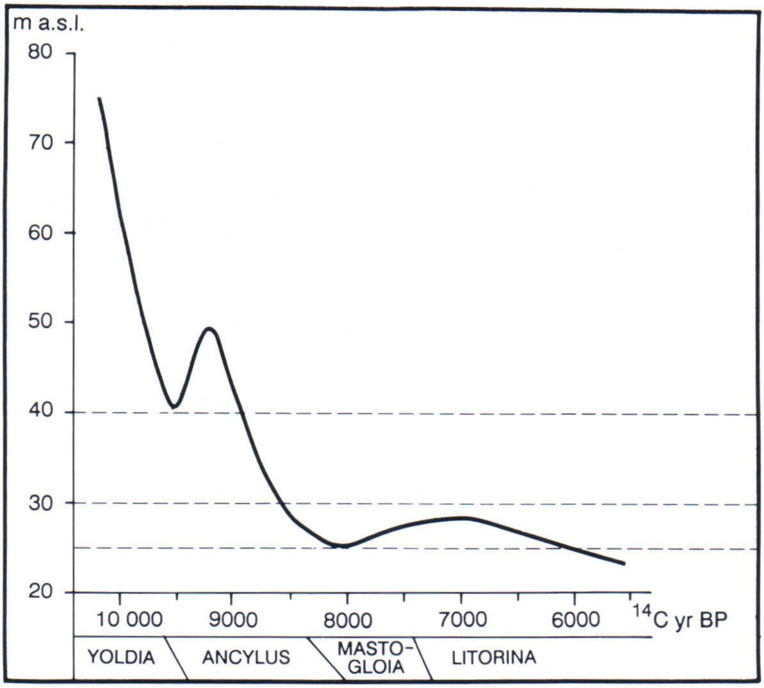

Fig. 7. Tentative shore displacement curve for the 28 m Litorina Sea isobase in the Epoo area. The curve is based on the present material and on the curves and Baltic Sea stage boundaries presented by Eronen (1976, 1983).

The palaeogeographical development at Epoo

The succession described above is compatible with the stratigraphy at the Epoo site (Fig. 2). The stratified (varved) clay, referring to the proximity of the retreating ice front, at the bottom of the section was most probably deposited during the Yoldia stage (lasting from about 10 200 to 9600 yr BP in southern Finland). It could be even older if an erosive phase causing a hiatus existed during the low water level (c. 40 m) stage close to the minimum of the Yoldia regression. No analyses were made on this basal layer. The conclusions drawn of the origin of the varved clay gain support when the overlying »blue clay» is examined. Both the pollen and diatom data (Figs. 3 and 4) on this stratum indicate a rapid regressive phase of the Ancylus Lake starting at 9300 yr BP and continuing to 8500 yr BP (strong dominance of *Pinus* pollen and presence of »Ancylus flora»).

The main topographical features of the surroundings of the site are presented in Fig. 6. The crucial points are the sandy »thresholds» northwest and southwest of the pit. These sills, which form part of an esker, played a major role during the change of the environment from an archipelago to a sheltered Litorina bay.

The sand layer at 340—270 cm might be attributed to a lowering of the water level to such an altitude (slightly above 35 m a.s.l.) that the southern sandy »threshold» of the forming bay (Fig. 6) was intensely eroded. An age of around 8700 yr BP is referred for this event. Abrupt changes in the biostratigraphy suggest that there may have been a gap in the deposit, most probably at the top of the blue gyttja-clay (Fig. 2). The deposition of the sand layer may have been quite drastic because of the rapid regression of the water level (as much as 5 m/century).

After the change in the sedimentary environment from open water conditions into a calm bay, a sequence of gyttja-clay rich in sulphide and plant macrofossils with intervening sand layers was deposited. The time interval is about 8500—

6000 yr BP, which refers to the Mastogloia and Litorina Seas. It is not known exactly when the slowing regression culminated, turning into a weak transgression in this region. The amplitude of the Mastogloia-Litorina transgression here was only a couple of metres.

The connections with a larger water body via the western »threshold» (Fig. 6) of the bay must have dominated the hydrography of the area during the time span 8500—6000 yr BP. The presence of black sulphide clay in the off-shore sediments (Ignatius *et al.* 1981) has been attributed to a fundamental change in hydrographic conditions. Such a change, believed to indicate a pronounced increase in salinity, does not explain the existence of sulphide clay at Epoo. Here the diatom spectra representing the time in question clearly reflect fresh-water conditions. It is possible that the formation of sulphide was post-depositional. The radiocarbon-date of the log of *Alnus* (8130 ± 50 yr BP) is the oldest age of alder wood ever recorded in Finland. It gives an age of about 8000 yr BP for the lower boundary of the sulphide clay (250 cm).

The immigration of the brackish-water diatom flora occurred at a depth of about 140 cm. Some 10 cm deeper, weak impulse of the Mastogloia phase can be distinguished. The start of the rational curve of *Tilia* coincides well with the start of the »true» Litorina stage. Both events are commonly dated to be slightly older than 7000 yr BP in southern Finland. The peak of the Litorina transgression close to that date and the following drop in water level leading to a shallow littoral environment caused disturbances in the uppermost part of the sediment sequence as a result of erosion and redeposition.

The sea level fell below 25 m a.s.l. soon after the deposition of the sandy drift peat at about 6000 yr BP. This is consistent with the data on the neighbouring basins (Fig. 1) according to which the sea level was at about 28 m a.s.l. at 6200 yr BP and at 24 m a.s.l. at 5600—5700 yr BP. The topmost sand horizon deposited in a beach environment, possibly during a storm.

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