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THE HOLOCENE SEA LEVEL RISE IN THE SOUTHERN BALTIC AS REFLECTED IN COASTAL PEAT SEQUENCES

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Abstract. Coastal peatlands depend in respect to their vertical growth totally on the sea level, are witnesses of its variations and, furthermore, preserve remnants of organisms which permit conclusions about the nutrient content and salinity of the flood water and thus of the surrounding sea. Black layers which occur frequently in the peat profiles point to evolution phases whereas the sea level fell or the mire became desiccated. Around thirty radiocarbon data, data from pollen and diatom analyses as well as from geochemical investigations provide the base to reconstruct the sea level history. The placement of particular transgression/regression stages could be determined with a higher accuracy than before and demonstrate a strong correlation to climate oscillations such as to the Late Bronze Age dry period or the Little Ice Age climate deterioration. Uncertainties still remain in regard to the regression magnitudes and to the length of the hiatuses in the peat sequences.

Key words: coastal peatland, Holocene sea level evolution, sea level – climate relation, West Pomeranian coast, Baltic Sea.

INTRODUCTION

Mires are archives of landscape development, because vegetation remnants are preserved in an anoxic environment for a long time and hardly removed or changed after sedimentation. Therefore highly resolved and selective stratigraphy can be obtained from peat profiles. Moreover, coastal grass peats depend in respect to their vertical growth totally on the sea level, are witnesses of its variations and, furthermore, preserve remnants of organisms which permit conclusions about the nutrient content and salinity of the flood water and thus of the surrounding sea.

Coastal peatlands develop on sections of the West Pomeranian coast with minor hydrodynamical stress and where reeds come into being in place of a beach. Such circumstances are common on the inner lagoon coastal waters locally called "Bodden". The extension of the peatlands in the landward direction depends on the increasing height of the land surface and growing distance from the groundwater and, in the seaward direction, on the increasing mechanical power of waves, currents and drifting ice. As the dominant species, firstly *Phragmites australis* appears, and more seawards *Bolboschoenus maritimus*, too (Slobodda, 1992). All coastal mires, which have a sufficient thickness, possess such a reed/sedge peat base, the growth of which has been induced by the rising sea and whose development started in the middle Atlantic to the Subboreal depending on the elevation of the mineral subground.

The dependence of the *Phragmites* peat surface on the vicinal sea level is quite marked and is restricted to an interval of about +20 to –20 cm around the mean sea level (Krisch, 1978; Slobodda, 1992). Due to this strong correlation, a rising sea level causes a landward shift and a growing thickness of the mire, whereas a sea level fall leads to superficial desiccation and mineralisation (development of black layers, see below) and, accordingly, to a lowering of its surface.

The peat of the coastal reeds is characterised by low to high losses on ignition (up to 90%) depending on the distance from the shoreline and small dry bulk densities (about 0.1 g/cm^3). In the seaward direction, the peat is replaced successively by silicate mud and finally sand which originate from the shallow water areas and were deposited on the mire surface by waves during storms and higher water levels. Therefore, the sediment of the banks of the coastal peatlands are characterised by a very flat and inconspicuous levee-like ridge with a higher silt and sand content than in the areas located further landward.

Typically, in their upper section, the sediment sequences of the salt meadows change from pure reed peats into black muds (black layers), silt layers and finally into grass peats rich in mineral matter. The starting point of this alteration is a failure

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Table 1

Transgressional and regressional phases of the relative Holocene sea level evolution at the West Pomeranian coast (acc. to Janke, Lampe, 2000)

Transgression/Regression Phase	Code	Period
Recent transgression	RN	modern times
Late Subatlantic regression	RPL	Little Ice Age
Post-Littorina transgression	TPL	Medieval Warm Period
Regression ?	RL3	Migration Period
Littorina-3 transgression	TL3	Roman Age
Bronze Age regression	RL2	Late Bronze Age
Littorina-2 transgression	TL2	Early Subboreal
Littorina-1 regression	RL1	Late Atlantic
Littorina-1 transgression	TL1	Middle and Late Atlantic
Initial Littorina-1 transgression	TL1i	Early Atlantic

of the *Phragmites* reeds at about the closure of the pollen zone Xa due to a sea level regression (Jeschke, Lange, 1992). The dried areas were then used by Slavonic and German settlers as cattle pasture without much effort. Connected with the continuation of the sea level rise during the pollen zone Xb, the development of the grass peat started. The strongly competing reed was repressed due to the grazing cattle, whereas halophilic grasses and herbs were encouraged. Resulting from 800 years of interplay between flooding with material supply from the lagoons, accumulation of organic matter (predominantly of grass roots), and densification of the peaty soil due to the weight of the grazing cattle which prevents oxygenation and mineralisation of the organic matter, the coastal peatlands have the potential to grow to a higher elevation above sea level than any other peats (Jeschke, Lange, 1992; Kliewe, Janke, 1982; Lange *et al*., 1986). Typical levels are between 20 and 50 cm above mean sea level (m.s.l.).

The black layers developed due to peat oxidation caused by a groundwater or sea level fall. Such a fall could have been triggered by eustatic sea level variations, by climate changes to warmer and drier vegetation periods with intensified evapotranspiration and, in the past some hundred years, by anthropogenic drainage measures. Apart from their more or less intensive colour, the black layers can be identified macroscopically by their amorphous-smeary structure and the lack of synchronously built plant remains. The latter have been more or less totally mineralised, but younger roots from the layers above may have penetrated into the deposit and been preserved.

At the margin to the layer above, a hiatus is usually found and can be proved only by means of pollen analysis or absolute age dating. An important palynological criterion is the high pollen and spore density as a result of their relative enrichment during the degradation of the organic peat substance. Nonetheless, the ignition loss of the black layers amounts to about 40–65%, demonstrating that a strong peat accumulation must have preceded the subsequent degradation. In the upper section of the black layer a zone exists where *Pinnularia* diatoms are enriched. They point to an increase in subaerial conditions and a decreasing salinity during the turning period between the transgression and the following regression. Another criterion is provided by the relationship between organic carbon and dry bulk density, which are strongly negatively correlated throughout all profiles investigated. The only excursion from this relationship can be observed for the black layers, which are characterised by a density too high for their organic carbon content due to autocompaction and loss of pore volume during the mineralisation process. Further, the black layers are characterised by high degrees of humification and partly by enrichments of calcium and pedogenic iron, whereas the content of siliceous matter tend to a minimum.

To correlate the sea level variations detected in the peat sequences we refer to the scheme developed in the past some decades by Kliewe, Janke (1982) and Janke, Lampe (2000) for the West Pomeranian coast (Tab. 1). The phase like evolution of the relative sea level in the past 8000 years was found to be related predominantly to climate variations and therefore to the eustatic component, and was influenced by crustal or other movements only to a minor degree (non-eustatic components). According to the investigations of Kolp (1981) and Dietrich, Liebsch (2000), these latter movements cannot be neglected when comparing sites located perpendicularly to the neotectonic gradient. However, here we present results from coastal peatlands, which are located parallel to the gradient and have experienced only a small and similar neotectonic influence (Fig. 1). Therefore, this influencing component was neglected as a first approximation.

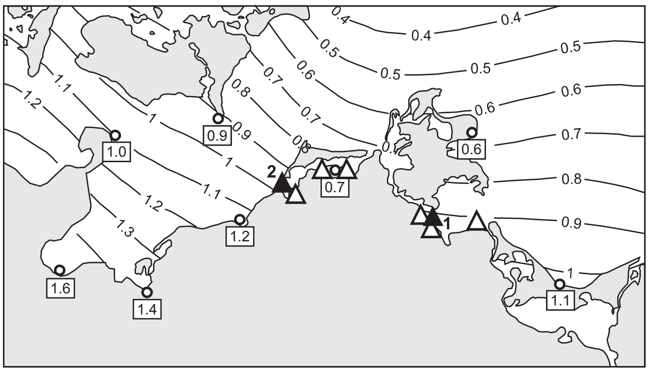


Fig. 1. Recent relative sea level movements in the area of the south Baltic Sea, calculated from gauge records by Dietrich and Liebsch (2000)

The black triangles depict the locations of the Kooser Wiesen site (1) and the Körkwitz site (2); the open triangles points to the locations from where radiocarbon data were used to reconstruct the sea level curve shown in Figure 4

Twelve coastal peat profiles from all sections of the Mecklenburg–West Pomeranian coast have been investigated until now. The distributions of the parameters showing the response of the peatlands affected by sea level changes can be exemplified here on two peat profiles only. These two profiles differ in many features and, therefore, point to the variability of the circumstances of their formation. Especially the exposition to the vicinal lagoon, the elevation of the mineral subground and the distance from the shoreline influence the specificity of the parameters investigated.

METHODS

Block samples were taken from a well-prepared and cleaned wall of a pit, digged into the mire, using a stainless steel frame, which was pushed into the vertical wall with a hammer. The blocks were unhinged, transported to the lab and cleaned again. Subsamples were taken in a resolution of 1cm for pollen and diatom analysis and 2 cm for geochemical investigations.

The pollen samples were treated in the classical way (acetolysis); samples with a higher silt/sand content were treated with fluoric acid too. At least 300 pollen grains per samples were counted, for the determination of the pollen density standard Lycopodium pills were used. 1–4 cm^3 sediment were annealed at 550°C, treated with 10% HCl and 10% H_2O_2 washed in purified water and mounted on a slide with Canada-balm. Geochemical analysis were conducted as follows: loss on ignition (LOI) was determined at 550°C, the ash was treated with Li-metaborate, and selected elements were determined by means of XRFA. C and S have been determined with an ELTRA-analyser. Humic substances were extracted by means of NaOH and Na-oxalat. Their amount — expressed in percent of organic matter (HZ) — has been determined using the spectral extinction at 530 nm (Schlichting *et al*., 1995).

RESULTS

KOOSER WIESEN

The profile was derived from a coastal mire about 1 m thick on the southwestern shore of the Greifswalder Bodden, which covers a flat, late glacial sand plain with only minor surface undulations. The investigation site is located directly on the southern bank of the Kooser See, a shallow bay which probably has been enlarged or even came into being due to heavy surges during the 14th century. The Kooser Wiesen area has never been diked and has been preserved as a nearly natural, undisturbed salt grassland. To the east, it borders on the Greifswalder Bodden with its wide opening to the Oder Bight, and, therefore, the site is significantly exposed to surges which are mostly caused by north-easterly gales. Today the Greifswalder Bodden is an eutrophic water with a salinity of *c.* 7.5 PSU. The profile investigated has a length of 87cm, and comprises the mire body and the underlying sand. With a sand surface located about 37 cm below the recent sea level, the mineral base of the site is located much higher than for many other coastal peatlands and was reached much later by the transgression.

From the viewpoint of pollen analysis only the first 83 cm below the ground surface (b.g.s.) could be analysed (Fig. 2, 3A). The uppermost sample of medium sand, normally without pollen grains, attracts attention with its extremely high *Ulmus* and *Tilia* and yet low *Polypodiales* pollen share. The number of *Chenopodiaceae* is also noticeable as well as pollen of the *Aster* type.

The hangingwall peat (81–72 cm b.g.s.) shows that a mire came into being surrounded by alder together with oak mixed forests rich in limes and elms. The higher content of monolete *Polypodiales* and *Sphagnum* points to a fast rise of the groundwater level, and the high content of non-arboreal pollen (above all *Poaceae* and *Cyperaceae*) and the appearance of *Chenopodiaceae* and *Compositae* (*Aster* type) reveal an environment close to a shore. The sediment from the base provides an age of 2555–1685 BC (no. 16, Fig. 4), which seems to be much too young. Another ^{14}C-date gives an age of 3490–2920 BC (no. 20, Fig. 4). The sediment still contains no diatoms.

Subsequently (72–64 cm b.g.s.), the mire developed into a coastal peatland with oak mixed forests rich in elms, limes and alders in the vicinity inland. In the final stage, a massive occurrence of *Thelypteris*, *Umbelliferae* and *Lythrum* is observable, accompanied by the appearance of *Hydrocotyle*-, *Menyanthes*-, *Valeriana dioica*-, *Lycopus*-, *Succisa*-, *Calystegia*- and *Filipendula*-type pollen grains. The existence of some brackish water diatoms demonstrates occasional flooding.

The next section (64–60 cm b.g.s.) is characterised by the lower black layer. The pollen distribution is still determined by quercetum mixtum with elm and lime and a high *Pinus* fraction. *Chenopodiaceae* appear only sporadically. Monolete *Polypodiales* increase which prefer an environment not influenced by brackish water. Pollen grains pointing to tillage and pastures are not yet observable. A ^{14}C-date provides an age of 2270–1985 BC (no. 15, Fig. 4).

Between 60 and 46 cm, mud of the L3-transgression (cf. Tab. 1) with intercalated humous layers appears. The terrestrial vicinity was covered with forests; no cereal pollen has been observed. *Chenopodiaceae* increase again. Later, the following features are evident: continuous but minor cultivation of cereals; first continuous appearance of *Plantago maritima*; very

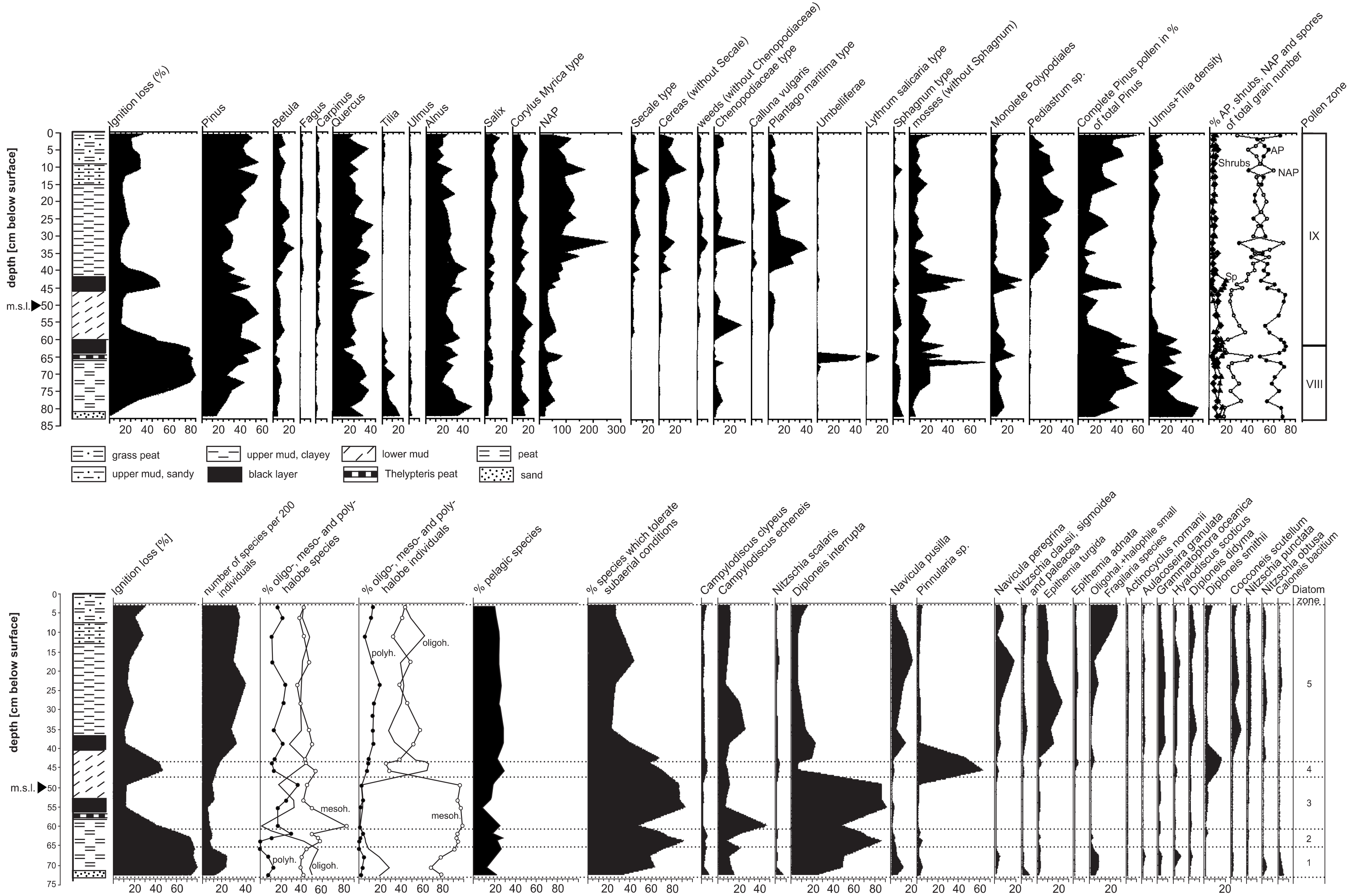


Fig. 2. Pollen and diatom diagram, Kooser Wiesen site, near Greifswald

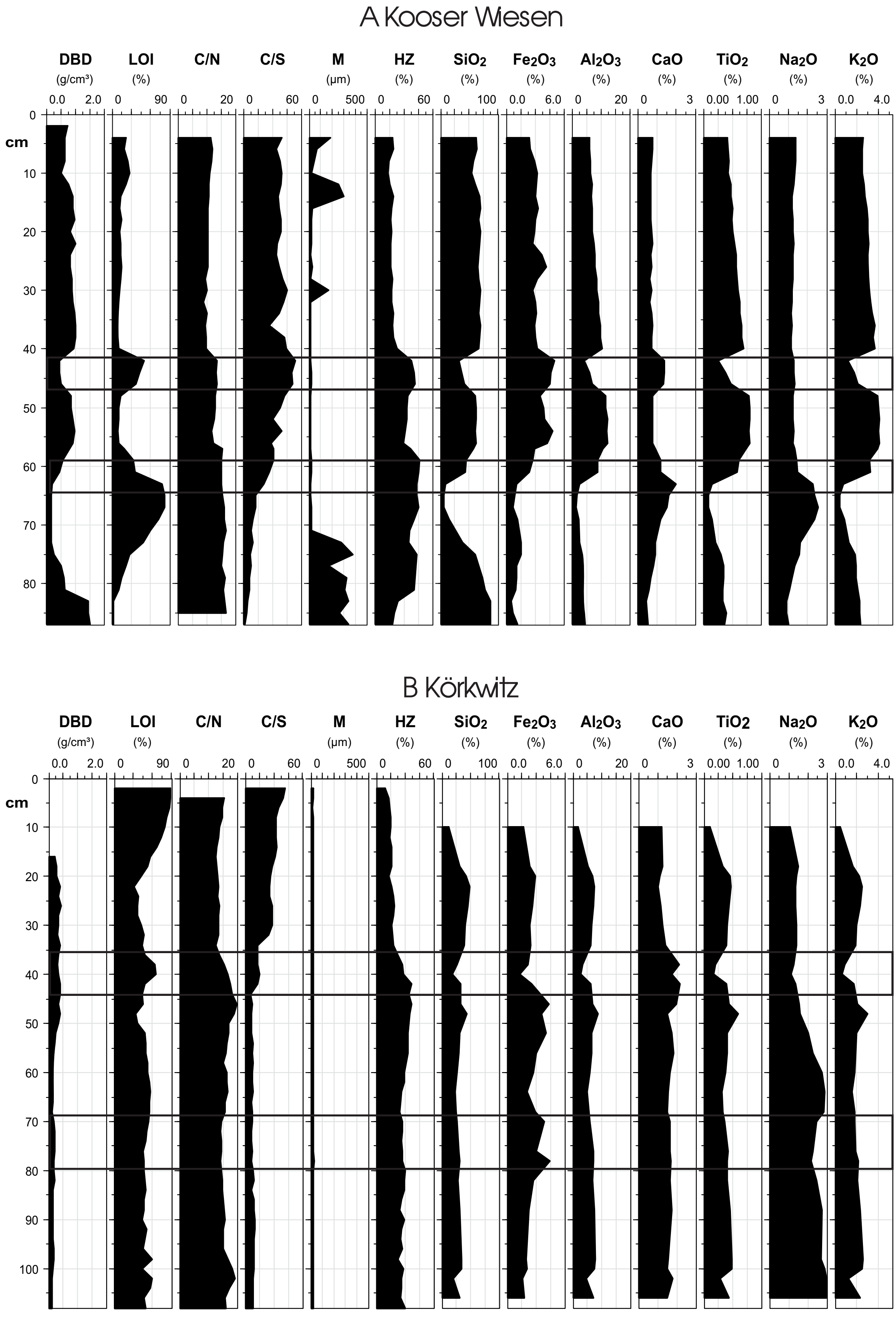
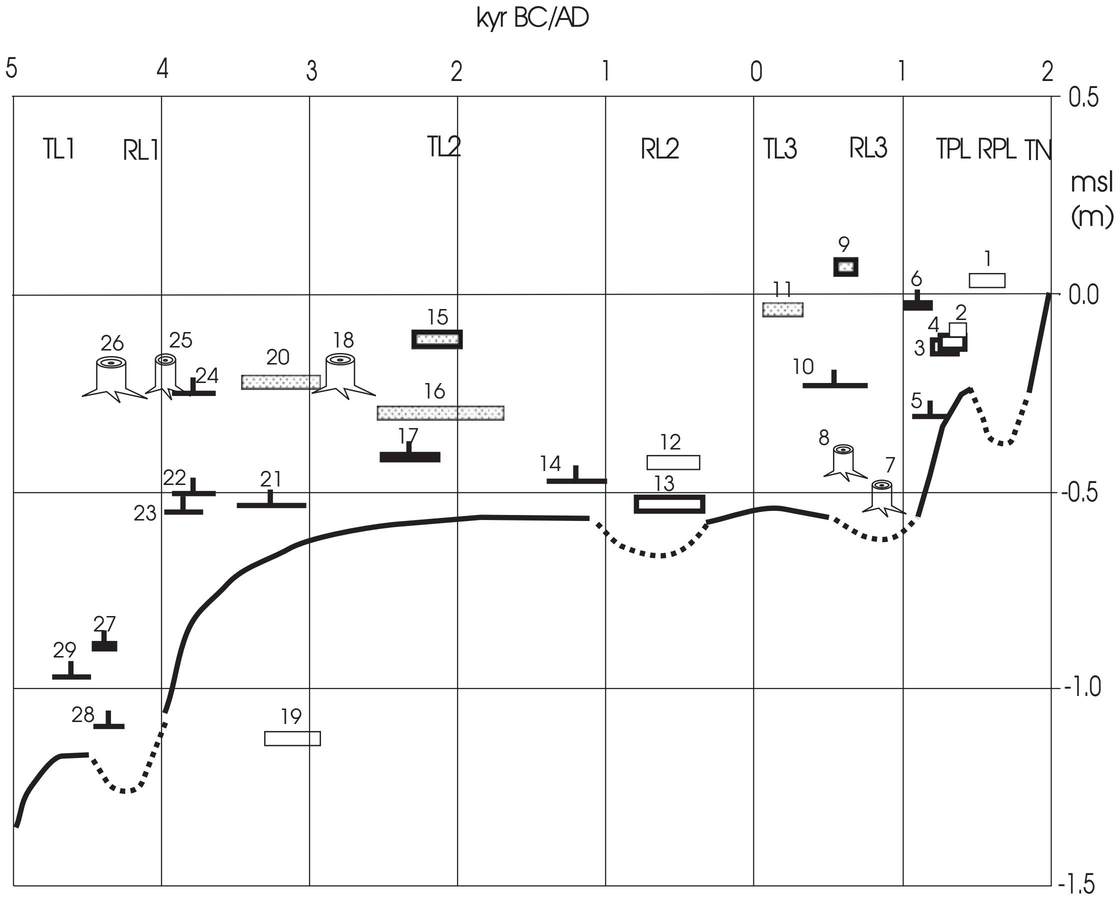


Fig. 3. Distribution of geochemical parameters: Kooser Wiesen site (A) and Körkwitz site (B)

The positions of the black layers are marked with black frames



No.	Profile/Sample	Lab.-No.	msl (m)	years BC/AD	
1	Körkwitz	Hv 23976	0,03	1445 - 1650	AD
2	Körkwitz	Hv 23673	-0,09	1300 - 1415	AD
3	Körkwitz	Hv 23675	-0,13	1260 - 1385	AD
4	Körkwitz	Hv 23674	-0,13	1165 - 1280	AD
5	Barth	Hv 23979	-0,31	1070 - 1295	AD
6	Struck	Hv 23981	-0,02	1025 - 1210	AD
7	Karrendorf, stump	Hv 24550	-0,60	775 - 885	AD
8	Koos, stump	Erl 2515	-0,45	620 - 660	AD
9	Kooser Wiesen	Gd 15292	0,07	560 - 670	AD
10	Barth	Hv 23978	-0,23	260 - 770	AD
11	Kooser Wiesen	Erl 2160	-0,04	-50 - 318	AD
12	Körkwitz	Hv 23977	-0,42	755 - 390	BC
13	Körkwitz	Hv 23676	-0,53	800 - 540	BC
14	Barth	Hv 23980	-0,47	1405 - 1005	BC
15	Kooser Wiesen	Gd 12355	-0,12	2270 - 1985	BC
16	Kooser Wiesen	Gd 15311	-0,30	2555 - 1685	BC
17	Struck	Hv 23982	-0,40	2560 - 2135	BC
18	Struck, stump 1	Gds 246	-0,25	2920 - 2790	BC
19	Körkwitz	Gd 15284	-1,13	3360 - 2935	BC
20	Kooser Wiesen	Gd 15308	-0,22	3490 - 2920	BC
21	Struck	Hv 23983	-0,52	3500 - 3035	BC
22	Recknitz mouth	Ki 3561	-0,50	3935 - 3665	BC
23	Karrendorf	Hv 23670	-0,55	3960 - 3700	BC
24	Struck, below stump 1	Gd 15309	-0,25	3965 - 3645	BC
25	Struck, stump 3	Gd 11350	-0,25	4040 - 3945	BC
26	Struck, stump 2	Gd 11350	-0,25	4450 - 4260	BC
27	Struck	Gd 12351	-0,90	4455 - 4335	BC
28	Fahrenkamp	Bln 2946	-1,10	4455 - 4255	BC
29	Struck	Gd 12354	-0,96	4690 - 4466	BC

^{14}C-data from
Kooser Wiesen
Körkwitz
similar profiles in the vicinity
width corresponds to the 1SD - interval,
bold frames or lines means that samples
were taken from a black layer

^{14}C-data from tree stumps

estimated relative sea level curve
sea level curve, not well proved

T..., R... : transgressions-/regression phases: L1...3 – Littorina-1...3, PL – Post-Littorina, N – modern times

Fig. 4. Depth–time distribution of radiocarbon dated samples from the Kooser Wiesen and Körkwitz sites and some other coastal peat sequences, located close to the sites investigated (cf. Fig. 1)

The sea level which drove the peat to grow is thought to be about 20 cm below the peat surface before the L2-regression. After the first silt rich mud layer was accumulated during the L3-transgression, the peat could grow to a higher level above the sea level, due to the low permeability of the underlying mud; today 20–50 cm above m.s.l. is mainly observed high density of pollen grains and spores; remains of a *Campylodiscus echeneis* flora, poor species diversity due to post sedimentary opal solution; also species such as *Diploneis interrupta* appear which tolerate subaeric conditions. ^{14}C-AMS-dated (probably redeposited) charcoal points to an age of –50 to 318 AD (no. 11, Fig. 4), i.e. the layer should be younger or at least of the same age.

The upper black layer (46–42 cm b.g.s.) is the result of peat mineralisation which developed during the Post-Littorina transgression. Due to the low content of silicate related matter and the high LOI, the growth of the peat during the transgression occurred fast and without extensive clastic inputs. A ^{14}C-date reveals an age of 560–670 AD (no. 9, Fig. 4), but this reflects the age of the organic matter, not of the phase of mineralisation. Mineralisation probably occurred during the culmination of the Little Ice Age, characterised by a climate with hot, dry summers and long cold winters. The higher concentrations of Fe and Ca stand for pedogenic processes and secondary enrichment under non-marine conditions. The pollen diagram is characterised by a high *Pinus* fraction and strong increase in some NBP components (such as *Poaceae* and *Cyperaceae*) and of *Polypodiaceae*. Further, only minor agricultural land use, a strong decrease in *Chenopodiaceae* and *Plantago maritima*, as well as a low pollen/spore density were observed. The section reveals the strongest deviation from the normal diatom assemblage with a strong increase of oligohalobic species, a predominance of *Pinnularia* sp. and *Diploneis smithii*.

Between 42–28 cm b.g.s., the profile is characterised by a very clayey mud, poor in humus. The pollen assemblage is indicated by the increasing usage of cereals and the first increase in *Botryococcus* and *Pediastrum*. A sharp decline in the curve, depicting complete *Pinus* pollen grains, points to increasing sediment transport and mixing. The increase in *Betula*, *Quercus* and *Carpinus* and the *Calluna* maximum between 38 and 33 cm are probably related to the Thirthy Years' War. Above 33 cm, the maxima of *Poaceae*, *Chenopodiaceae*, *Plantago lanceolata* and *Plantago maritima* have been observed and the agricultural use has been intensified.

Above (28–12 cm b.g.s.) the youngest increase in the *Pinus* curve was caused by the introduction of forestry and reveals high values until today. The convergent shoreline causes a higher sand content in the sediment and a lower pollen density. The still ascending cereal curve indicates the intensification of agricultural land use.

The uppermost section (12–0 cm b.g.s.) is characterised by a more sandy and humous grass peat. It was probably accumulated only after the surge of 1872, which built a prominent sand layer 14–15 cm b.g.s. below the surface. The farther approaching shoreline led to the deposition of tempestites and to an admixture of older and reworked sediments. Consequently the pollen assemblage can change so markedly that it no longer corresponds to the true pollen assemblage recently observed on salt meadows.

KÖRKWITZ

The profile is located on the Ribnitzer Wiesen south of the village Dändorf. The mire is about 4 m deep and consists predominantly of fenwood at the base, *Phragmites* peat and peat muds. The vicinal landscape is characterised by flat undulating sand plains, formerly used as arable land and recently covered with *Pinus* forests and pastures. The profile is located *c.* 200 m away from the recent shoreline of the Saaler Bodden, from which resuspended sediment material can hardly reach the location due to the dense reed belt. Since the Middle Ages, the salinity of the Saaler Bodden has decreased due to the ongoing coastal change and inlet closing, and amounts today to between 0.5 and 2 PSU. At the same time, the nutrient content increased to a polytrophic/hypertrophic degree, causing high mud sedimentation rates primarily in the southern part of the water. The section investigated chemically starts only at 108 cm (Fig. 3B), the palynological/diatomological investigation (Fig. 5) starts at 410 cm below the ground surface (b.g.s.).

The basal sands between 410 and 390 cm b.g.s. contain freshwater diatoms. Their age is difficult to determine due to only less preserved pollen grains, among them QM species and *Alnus*, but it is likely Early Atlantic (pollen zone VI). They are covered by a Gleysol (390–350 cm b.g.s.), which passes onwards into a peat. With the onset of the Littorina-I transgression, the site became a wet meadow with *Diploneis interrupta* as the main species (350–344 cm b.g.s., Fig. 5). The hanging-wall section (344–325 cm b.g.s.) depicts a bi-peaky *Campylodiscus echeneis* maximum, accompanied by high sponge needle values. As the only section it contains *Operculodinium centrocarpum* and demonstrates low values of the complete-*Pinus* curve. Towards the end of the stage the contact to the open sea was lost.

The next section reveals a marsh-like area with shallow waters in the vicinity and drift lines around (*Chenopodiaceae*). Among the diatoms *Diploneis interrupta* predominates, whereas in the pollen diagram a high NAP share has to be stated, particularly from plants growing in underwater, beach and drift line habitats (*Typha*, *Potamogeton*-type, *Cyperaceae*, *Chenopodiaceae*). This and the next section, up to 170 cm b.g.s., consist of organic mud and peat with an ignition loss of *c.* 80% and came into being in the Late Atlantic. Upwards the clastic material increases slowly, above 170 cm faster to 40–70%.

A peat sample taken at 137 cm b.g.s. reveals a ^{14}C-age of 3360–2935 BC (no. 19, Fig. 4). In the section up to 80 cm, the pollen diagram depicts a closed oak mixed forest, rich in *Corylus*, *Tilia* and *Ulmus* and some alder habitats. *Fagus*/*Carpinus* and cereals appear regularly. In the lower part some indicators for higher salinity have been proved (*Chenopodiaceae*, *Aster* type, fenestrate *Compositae*). The section is related to pollen zone VIIIa. The diatom flora — as far as preserved — consists only of *Diploneis interrupta* and *Campylodiscus echeneis*. The only slight increase in Na and LOI at about 100–90 cm b.g.s. is related to a transgression (which can only be the TL2, cf. Tab. 1) and to the subsequent stagnation of the sea level.

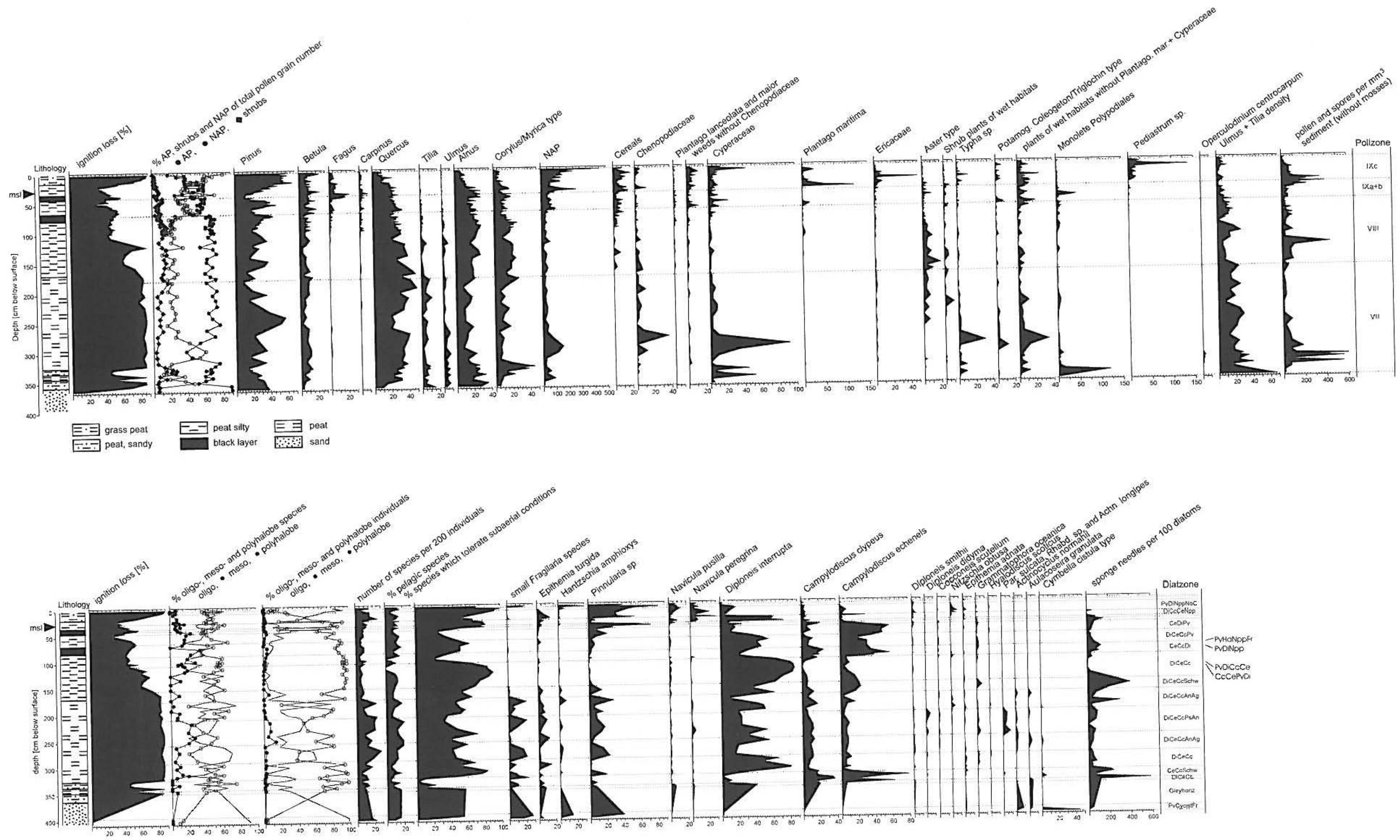


Fig. 5. Pollen and diatom diagram, Körkwitz site, near Ribnitz-Damgarten

In the succeeding layer up to 69 cm, the peat is black coloured. In this prominent layer the Fe-content and the bulk density is increased, the Na-content is decreased. In the lower part, between 75 and 80 cm, the organic substance seems to be more or less amorphous — except for the later permeated roots. The pollen diagram shows an alder rich, oak mixed forest, salinity indicators are lacking, and the diatom assemblage is dominated by *Diploneis interrupta*. In the upper part *Pinus* increases and wetness indicators too. At the upper boundary an abrupt change in favour of NBP and *Cyperaceae* occurs. The layer is apparently bipartite, which is confirmed also by the distribution of Fe and DBD. The peat oxidation horizon which points to desiccation and mineralisation is at located about 75 cm and yield a calibrated radiocarbon age of 800–540 BC (no. 13, Fig. 4). The upper part is influenced by the peat reconstitution, whereby older material is admixed into the growing younger layer. At its upper boundary the pollen zone IXa starts, which is confirmed by a ^{14}C-date of 755–390 BC (no. 12, Fig. 4).

Until 65 cm in the pollen diagram the Littorina-3--transgression is recognisable due to the change to NBP and *Cyperaceae*, a slight increase of *Chenopodiaceae* and the occurrence of *Plantago maritima* and *Triglochin*. The diatom assemblage is dominated by the *Campylodiscus echeneis* flora. The chemical parameters depict an increase in LOI, C/N and Na as well as decreasing concentrations of Fe and siliceous matter. However, the marine influence could be of only minor intensity because, at least from 65 cm onwards, all parameters show again a tendency to forest closure (German Tribes' Migration) and peat growths under freshwater conditions. At about 58 cm, the transition to pollen zone IXb occurs.

Until 48 cm b.g.s. a successive change at the location happened. The accumulation of organic carbon decreased due to stronger clastic inputs (increase of Si, Ti, K, Fe, DBD), which built the transition to the following mud sedimentation. In the vicinity grew an oak mixed forest rich in pines. Minor but regular cultivation of cereals can be proved. A phase of more frequent flooding is evident from a *Botryococcus* maximum, the first density maximum and a LOI-minimum at 48 cm b.g.s. The diatom assemblage remains unchanged.

Directly above, the upper black layer is located (36–46 cm), for which a bipartite evolution can be demonstrated. The growth of the peat was initiated by a water level rise, as revealed by wetness indicators such as *Succisa*, *Valeriana*, *Malva althea*, *Lysimachia*, *Lycopus*, *Lythrum* and *Sphagnum*. The high BP-values point to a widely forest covered landscape initially, although continuous cereal cultivation is traceable. *Pinus* decreases strongly in favour of *Fagus*/*Carpinus*, and the NBP increase rapidly. At 40 cm b.g.s. the pollen zone IXc is reached, and at 35 cm b.g.s. the *Fagus*/*Carpinus* maximum of the Slavonic period has been noticed. Two radiocarbon data taken between 36–38 cm b.g.s. in the uppermost part of the black layer provide 1165–1280 AD and 1260–1385 AD (no. 4 and 3, Fig. 4).

At 36 cm b.g.s. NBP and cereals show particular high values and mark the onset of the German colonisation. A ^{14}C-date at 32–34 cm provides 1300–1415 AD (no. 2, Fig. 4) and is in good agreement. Salinity indicators are not yet found. In the diatom assemblages *Pinnularia* species dominate; *Diploneis interrupta*, *Cymbella aspera* and others are also detectable. The second phase comprises of the surface lowering and mineralisation of these layers, changing their properties and producing a hiatus. The C/N-values decreases due to peat degradation and nitrogen release; pedogenic Fe and Ca are enriched secondarily. The pollen/spores density increases markedly.

During the following period characterised by a lower water level, which probably rose slowly, a very muddy grass peat started to grow (above 36 cm b.g.s.). It is characterised by an extremely high NBP content caused by the medieval clear cuttings and a corresponding maximum of *Plantago maritima*, secondarily of *Chenopodiaceae* too. The salinity in the lagoonal waters seems to be still high. But the curves for *Botryococcus* and *Pediastrum* ascend fast and indicate a first eutrophication episode caused by water isolation and desalinisation, which is also traceable by the increasing C/S-ratio. The maximum coverage with forests during the second half of the 17th century, due to the Thirty Years' War and the contemporary low cereal cultivation, was found at 23–29 cm b.g.s. A ^{14}C-date (1445–1650 AD; no. 1, Fig. 4) at 21–22 cm b.g.s. confirms this interpretation. The diatom flora is still dominated by *Diploneis interrupta*, supplemented by some robust brackish water diatom species.

Above 18 cm b.g.s. the sedimentation milieu changed. The high number of complete *Pinus* pollen grains demonstrates a sedation of the accumulation area; redepositions and inputs of resuspended material became less important. The mud deposition ceased and a grass peat very rich in organic carbon was accumulated. Contemporarily P increases as an eutrophication indicator and above 12 cm — Zn as an industrialisation indicator (not shown in Fig. 5). Due to the successive desalinisation of the vicinal water the C/S-relation depicts a limnic milieu. A durable fixation of sulphides did not occur. The sedimentation succeeded fast (low pollen density) and humus compounds (HZ) achieved only minor degrees of polymerisation. In the pollen diagram, the BP decreases in favour of grasses, and cereal pollen grains are also found in lesser number. In the diatom assemblage, generally poor in species, *Pinnularia* dominates, accompanied by species which tolerate subaerial conditions and low salinity.

It has to be stated that the diatom flora of the profile is poor in species. However, their distribution indicates salinity variations which have happened during the mire evolution in the Younger Holocene. The sections predominated by the *Diploneis interrupta* or the *Pinnularia* flora alternate with sections characterised by the predominance of *Campylodiscus echeneis* (173–140, 107–90 and 66–43 cm b.g.s.). It is assumed that these variations correspond to alternating transgressive and regressive stages (e.g. the Subboreal L2-transgression between 173 and 140 cm). This assumption has to be corroborated by further investigations.

DISCUSSION AND CONCLUSIONS

The radiocarbon data available from both profiles as well as from similar coastal peat sequences located at the coast of West Pomeranian lagoons and finally from in situ buried tree stumps found in the vicinity of these locations are depicted in Figure 4. The sea level curve which can be determined form the distribution of the dated samples in the depth-time diagram reveals that the sea level reached already at 4000 BC a position of about –1 m related to the recent mean sea level (m.s.l.). This finding is in accordance with results of archaeological excavations where dugout boats have been found at a coastal site in the city of Stralsund, at a depth of –1.7 m m.s.l., belonging to the Ertebølle culture and dated to about 4500 BC. However, the data from the Kooser Wiesen site (no. 15, 16, 20, Fig. 4) point to a higher water level position, which is believed to be the water table of a separate lake, located near to the coast and surrounded by a mire, but not yet directly influenced by the sea level. Further, the deep lying sample 19 from the Körkwitz site shows that perhaps this site experienced a certain subsidence, which ceased later. Because the difference is small, the autocompaction of the 4 m thick peat body could possibly explain it, but small differential movements of the Earth's crust are possible too. Further investigations are needed to solve this problem.

The occurrence of a black layer at the Struck site (no. 27) suggests the existence of a regression phase at about 4000 BC, as assumed by Kliewe, Janke (1982) and Janke, Lampe (2000). Also in the Körkwitz profile a third black layer could be found, which is located at 145 cm b.g.s., and is characterised by an extremly high pollen and spore number per mm^3 of sediment (Fig. 2). This black layer is not yet radiocarbon dated but must be slightly older than 3300 BC, as shown by the sample 19 (Fig. 4).

At about 800 BC, the water level curves show another slight regression or retardation phase in the mainly ascending trend, as revealed by the samples 13 and 17, both taken from black layers (Fig. 4). We assume that this phase coincide with the Urnfield Bronze Age which is thought to be a cool and dry phase in Central Europe. The large time difference of more than 1000 years between the age of sample 17 and this phase is probably caused by the loss of the upper peat layers due to strong mineralisation, whereby older layers influenced by the oxidation process have been dated.

A convincing argument for a sea level not higher than –60 cm m.s.l. at about 650 AD provides an oak stump, found close to the Kooser Wiesen site still rooting in the ground and covered by a coastal peat sequence (no. 7, Fig. 4). It delivers also an imagination to what extent the surface of the coastal mires could grow above the water table (cf. no. 8–10, having nearly the same age). The stump show *c.* 140 tree rings but due to bad growing conditions it could not be dated dendrochronologically. Shortly after the time the oak grew, the site was covered by marine influenced peat, identifying the onset of another transgression phase which lasted at least until 1300 AD. Samples 3, 4, 6 and 9 have been taken from upper black layers and point to a regression/desiccation phase younger than 1300 AD, which coincides with the Little Ice Age. The extend of the regression cannot be determined but it is well proved by gauge data, that the sea level rose in the past 150 years around 20 cm at the West Pomeranian coast (Dietrich, Liebsch, 2000). Therefore, during the culmination of the Little Ice Age at about 1700 AD the sea level is believed to be located at about –35 to –40 cm m.s.l.

The data from the coastal mires provide valuable insights into the sea level history of the past 6000 years. It could be shown that periodical sea level fluctuations of a range of 1 m, as sometimes discussed in the literature, are not detectable in the mire deposits along the West Pomeranian coast. In fact, the mostly indistinct black layers demonstrate that throughout the past 5000 to 6000 years the sea level moved only in the range of some decimetres. Further, the placement of the particular transgression/regression stages could be determined with a higher accuracy than before and demonstrate a strong correlation to climate oscillations such as the Late Bronze Age dry period or the Little Ice Age climate deterioration. Uncertainties still remain in regard to the regression magnitudes and to the length of the hiatuses in the peat sequences. Due to the different response of the mires concerning the releasing sea level fall the determined hiatus lengths will probably be of only local validity. A comparison of the height position of the black layers in respect to the recent sea level displays that different relative post-depositional movements occurred hardly during the past 3000 years. But for the times before the curves diverge which lead to the assumption, that the pattern of movement behaviour of the Earth's crust was different than after 1000 BC. However, no firm statements can be made without further investigations to decode the amount and the causes of the differences.

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