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NEW PALYNOLOGICAL EVIDENCE AND CORRELATION OF EARLY PALAEOLITHIC SITES SCHÖNINGEN 12 B AND 13 II, SCHÖNINGEN OPEN LIGNITE MINE

The Pleistocene sequence of open mine Schöningen (Niedersachsen, Germany; **fig. 1**) is of significance for the subdivision of the glaciated upper Middle Pleistocene of western Central Europe (Thieme et al. 1987; Urban et al. 1988; 1991a; 1991b; Urban 1995a; 1995b; 1996a; 1996b; 1999; 2002) and for the provision of archaeological evidence for the early appearance of *Homo erectus* in Northern Germany (Thieme et al. 1987; 1992; 1993; Thieme / Maier 1995).

The Pleistocene and Holocene are composed of various types of sediment including peat, muddy and silty layers from former swamps, lakes, peat bogs, and river flood plains that contain characteristic pollen assemblages. Fossil remains of molluscs, small and large mammals, fishes, reptiles and plant macro fossils are fairly abundant in some layers (Böhme 2000; 2007; Jechorek 2000; Jechorek et al. 2007; van Kolfschoten 1995; van Kolfschoten et al. 2007; Mania / Mai 2001; Mania 2007; Urban 2007).

Classical Holsteinian interglacial and Mißaue 1, Mißaue 2 and SU A interstadial deposits are underlain by Elsterian glacial and Late Elsterian interstadial sediments (Urban et al. 1991b) in the northern mining area. D. Mania (1998) introduced a schematic simplified cross section (**fig. 2**) indicating six superimposed sequences of significant channel fillings/cycles which have been subject to debate by several authors. He termed the Holsteinian deposits found in the northern mining field channel I/cycle I. Channel II representing the Reinsdorf interglacial sequence exposed in the southern mining area and the Schöningen Interglacial (channel III) peat deposits from the northern mining field represent warm climatic periods older than the Saalian ice advance. Channel III deposits have been found only in the northern mining area with organic facies. The climatostratigraphic significance of a pedosequence of pseudogleyic, alluvial loess (channel IV, Altermann / Mania 2007), overlying the older Saalian till (Drenthe stadium) in the southern mining area still remains unknown. The sediment sequence of travertine, silts and peat (channel V) has been correlated with the Eemian and to stage 5e of the marine isotope record (Urban et al. 1991a; Heijnis 1992; Heijnis / Urban 1995). Those sediments are overlain by Early Weichselian silts composed of loess and organic soil horizons.

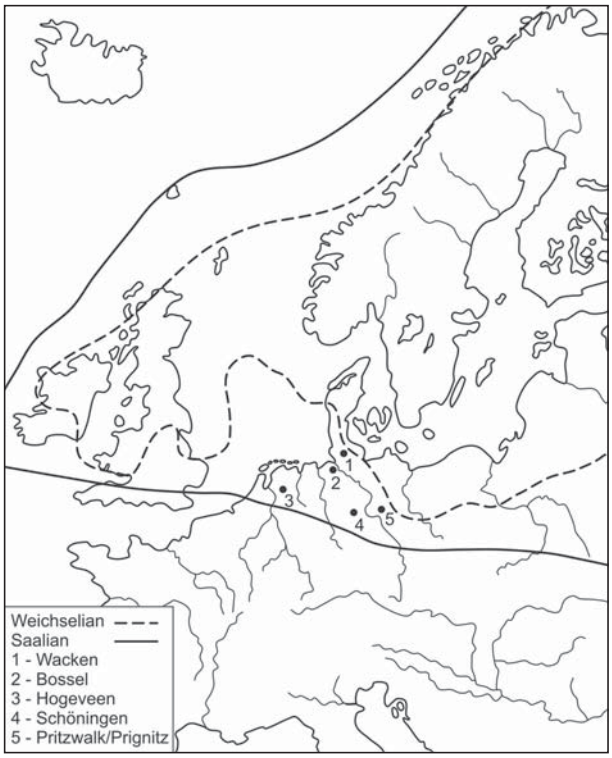

Fig. 1 Location of sites Schöningen (Lkr. Helmstedt), Wacken (Kr. Steinburg), Bossel (Lkr. Stade), Hoogeveen (prov. Drenthe/NL) and Pritzwalk (Lkr. Prignitz) and maximum extension of Weichselian and Saalian ice sheets.

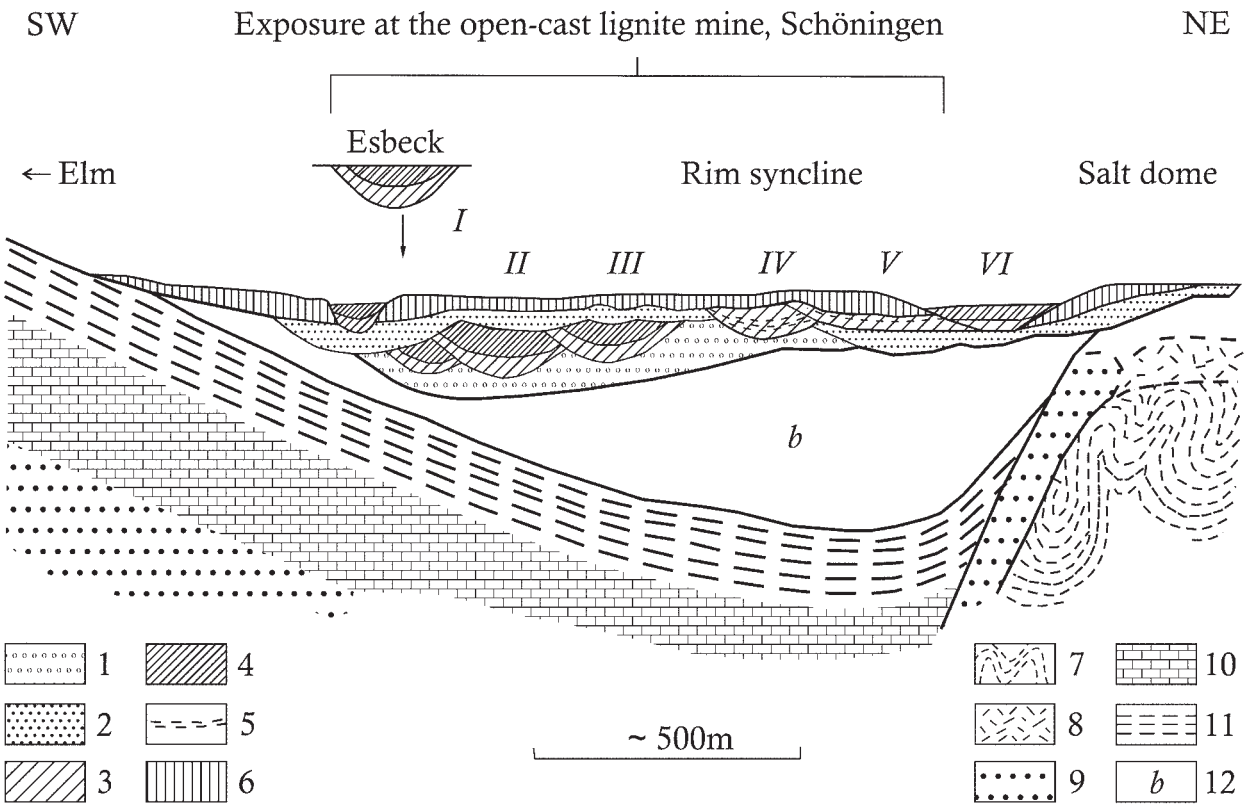

Fig. 2 Schematic framed transect through the Quaternary sedimentary cycles I-VI (after Mania 1995, modified; Urban 1998; 2007; Thieme 1997). – Cycles I, III, V, VI and sediments of the Esbeck Interstadial have been exposed in superposition in the northern mining field (Urban 2007), whereas sediments of cycle I and cycle II occur in superposition in the southern mining field (Mania 1995; Thieme 1995, Urban 2007). Pedocomplex IV is hitherto only known from the southern mining field (Mania 1995). – The actual distance between cycle VI sediment beds and the salt dome is about 2km (this distance is not shown to scale). – Esbeck = Esbeck interstadial; cycle I (sensu strictu, Urban 1996b) = Holsteinian; cycle I/II = Late Elsterian/Holsteinian/Reinsdorf interglacial (?) (Urban 2007; Urban et al. 2011) (southern mining field); cycle III = Schöningen interglacial; cycle IV = Pedocomplex; cycle V= Eemian; cycle VI = Late Glacial and Holocene. – **1** Elsterian glacial deposits. – **2** Saalian glacial deposits. – **3** lacustrine deposits. – **4** limnic telmatic sequences. – **5** soil complexes. – **6** loess deposits. – **7** evaporites. – **8** gypsum cap rock. – **9** Buntsandstein. – **10** Triassic limestone (Muschelkalk). – **11** Triassic deposits (Keuper). – **12** Tertiary deposits.

Solifluction layers and fluvial deposits mark the onset of a strong cooling. Late Weichselian Alleröd peat with Laacher See tuff and Younger Dryas silts underlie the Holocene sequence which is designated channel VI (Urban et al. 1988) (**fig. 2**). Sediments of channel V have been exposed only in the northern mining area and are described in detail only for that part of the mine.

The stratigraphic position of the classical Holsteinian deposits, especially in relation to the Reinsdorf sequence (Urban 2007) and correlation with other pollen records and the marine isotope statigraphy, are still a matter of debate. The age and stratigraphic position of the upper Middle Pleistocene Reinsdorf sequence which contains archaeological horizons with wooden throwing spears (Thieme 1996; 1997; 1998; 1999), are of particular interest.

Profile series have been salvaged by Hartmut Thieme and his excavation team from the ongoing mining process during the past decades and have been successively analysed. In order to achieve a better understanding of the palaeoenvironmental conditions and to determine the chronology of channel II infillings of mine Schöningen, we newly compiled palynological and sedimentological data of the archaeological sites Schöningen 12 (12 A, 12 B; **figs 3-4**; Thieme et al. 1993, Thieme / Maier 1995) and Schöningen 13 II (K 13 II;

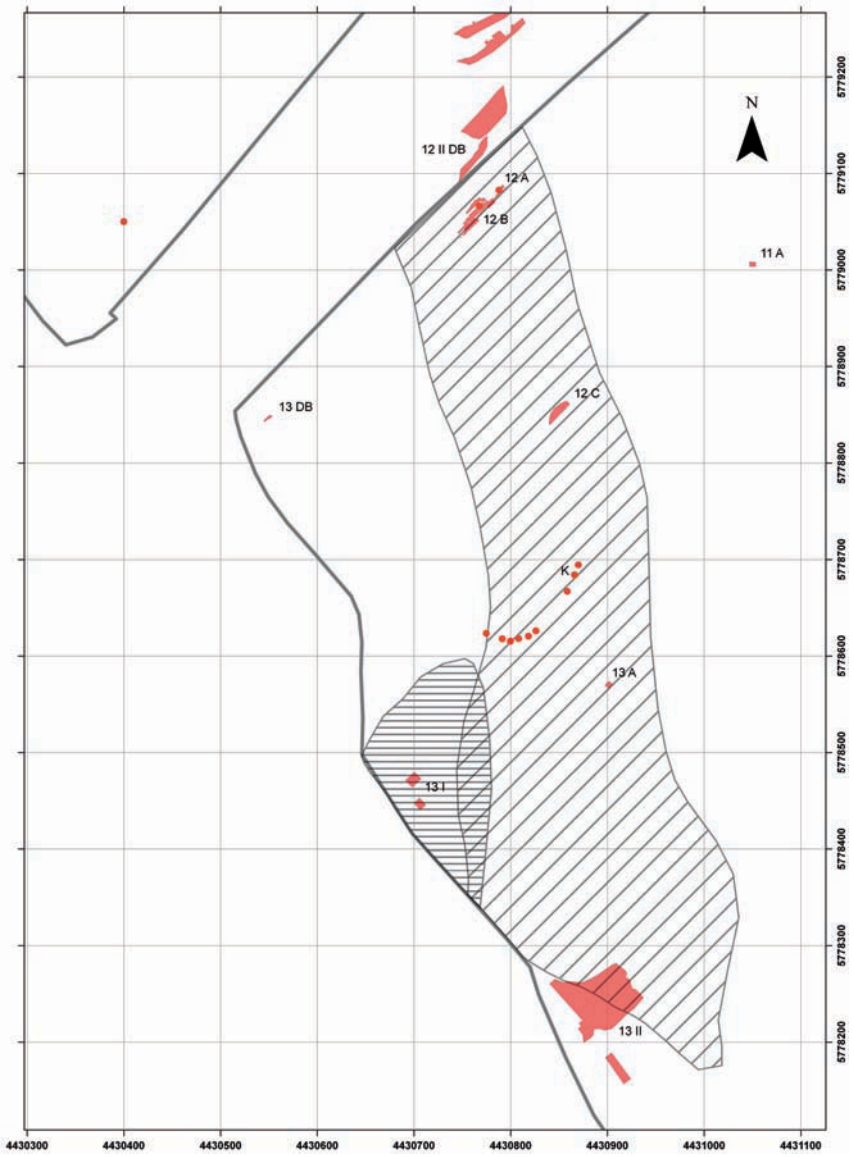

Fig. 3 Map of the Southern Mining Field showing the position of archaeological sites Schöningen, Schö 12 B (position of profiles 12 A, 12 B, first archaeological horizon and sample 12 A1, second archaeological horizon) and of Schö 13 II (position of profile 13 II K). – (Map compiled by U. Böhner, Niedersächsisches Landesamt für Denkmalpflege).

fig. 3). For comparison with the Schöningen 13 II (96) lithology, we refer to Thieme (1998). The palynological data will be presented in relation to archaeological horizons and new dating approaches will be referred to briefly. An evaluation of older Th/U ages on the Schöningen sequence will be discussed using new ^{230}Th/U dating results of sequence 13 II (2003) in the corresponding article (Sierralta et al., this volume).

MATERIALS AND METHODS: SEDIMENTOLOGY AND PALYNOLOGY

Describing the biostratigraphical position and environmental character of particular horizons within the interglacial hitherto only briefly depicted in Thieme et al. (1993) should lead to a better understanding of the relation between archaeological features, palaeoenvironmental conditions and bio- and chronostratigraphy.

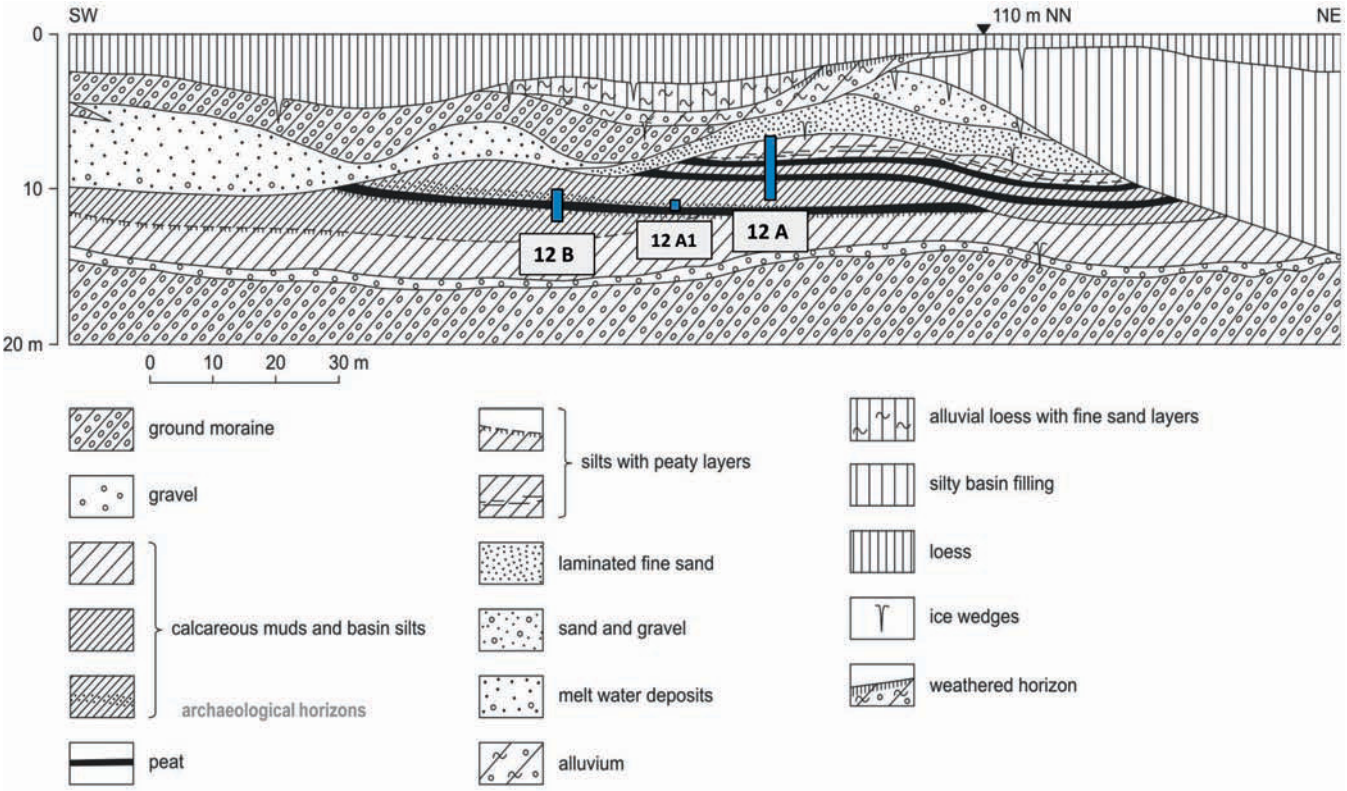

Fig. 4 Geological setting of the sequence Schöningen 12 II. Bars are schematically marking the sampling position of profile 12 A (92) and 12 B (92). The position of sample 12 A1 of the second archaeological horizon is at the base of profile 12 A (92). – (After Mania 1995).

Samples were taken from the archaeological site Schöningen 12 containing the first archaeological horizon (profile and pollen sequence 12 B) and the second archaeological horizon (profile and pollen sequence 12 A), during the first Palaeolithic archaeological campaign in the north-west part of the southern mining area (**fig. 4**). Samples from sequence 13 II K were taken from the southern margin of this mining field during the same field campaign in 1992. A sequence of profiles C, D, E, F, G, H, K, L, M, N, has been mapped by Mania (map of detailed cross section of H. Thieme and D. Mania 22.8.1992, unpublished; compare **fig. 3**). Profiles F and G were sampled for sedimentological studies only while, profile K, spanning 8 meters, was also sampled for palynological study.

Sampling of fine grained and organic deposits at archaeological site Schöningen 12 and site 13 II, profile 13 K, described here was carried out from exposures using 25 x 7 x 5 cm sized steel boxes (**fig. 5**) or by taking 10 × 10 cm samples. Additional depth related samples, including soil monoliths, were taken for botanical and geochemical analysis (**figs 6-7**).

The texture of the horizons was determined by the hydrometer method (van Reeuwijk 1992). The same samples were analyzed for their pH in a 1:2.5 0.01 M $CaCl_2$-suspension, for their carbonate content following gasometric determination with the Scheibler apparatus and for soluble salts (Electrical Conductivity, EC) according to VDLUFA (1991). Organic carbon (OC) was determined using the Walkley-Black procedure (Page et al. 1982) which detects pedogenic carbon. For palynological analysis, including charcoal particles, 10-20 g samples were treated by standard palynological methods. These procedures included dispersion

Fig. 5 Sediment profile and sampling for sedimentological and palynologcal investigations in metal boxes at profile Schöningen 12 A (92) during the excavation period. – (Photo P. Pfarr).

Fig. 6 Soil monolith sampling at profile Schöningen 12 B (92) containing the first archaeological horizon. – (Photo B. Urban).

with 10% NaOH, carbonate removal by 10% HCl, flotation to separate organics from the inorganic matrix using sodium metatungstate ($3Na_2\ WO_4\ 5WO_2\ H_2O$) and acetolysis (Faegri / Iversen 1989; Moore et al. 1991). Prepared residues were embedded in glycerine on microscope slides. Pollen and spores were identified with the aid of the atlases of Moore et al. (1991), Beug (2004) and Faegri / Iversen (1989) and a reference collection of the Laboratory of the Institute of Ecology, Subject Area Landscape Change at Leuphana University of Lüneburg. Counts were made to a pollen sum (100%) of, on average, 400-500 arboreal (AP) and non-arboreal pollen (NAP) per sample excluding aquatic taxa, Cyperaceae and Ericaceae as well as fern and moss spores and reworked palynomorphs. Pollen calculations and diagram construction were performed with the software package TILIA, TILIA GRAPH and TILIA VIEW (Grimm 1990).

RESULTS

Sedimentology and palynology of profiles of the Reinsdorf sequence

Profile Schöningen 12 B containing the first archaeological horizon

Profile 12 B spans 155 cm, starting at the bottom of the sequence (155-130 cm) with a green, strong calcareous silt (40-80%) which is low in organic carbon (ca. 1.2%) (**fig. 8**). Between 130 and 80 cm the

Fig. 7 Photo taken from soil monolith of the upper parts of profile Schöningen 12 B (92) in organic richer facies. – (Photo B. Urban).

sandy, lower carbonate containing (13-20%) silt with mollusc shells and pieces of wood, shows varying organic carbon contents (2-ca. 8%). The sequence shows, especially in this part of the profile, fine laminations of silty layers alternating with sandy horizons, partly rich in well preserved plant remains; these being characteristic for bank sediments of a shallow water body. Between ca. 80 and 70 cm (**figs 7-8**), a decomposed fen peat layer is intercalated having a carbon content of about 19%. It is poor in carbonate and contains slightly higher amounts of soluble salts. The peat layer is overlain by a sandy, slightly organic silt containing wood (70-55 cm). The first archaeological horizon (50-30 cm) was found in a carbonate rich (14%), pebbly to coarse sand characteristic of fluvial activity at the margin of a former shoreline of a shallow lake; it has an organic carbon content of about 2% (**figs 8-9**). This layer is rich in wood, bones and artefacts indicative of human activity. The top of the profile between 30 and 0 cm is made up of a dark brownish organic silt (OC 5%), rich in plant macro remains. The pH of almost all the profile is alkaline to slightly acid due to the carbonate content.

The pollen diagram (**fig. 9; tab. 1**) can be divided into five zones/subzones which could be directly correlated with local pollen assemblage zones (LPAZ) of site 13 II (Urban 1995a; 2007) and were, therefore, given the same main notations. The pollen zones and subzones are described from bottom to top.

LPAZ R1 b (150-130 cm): Quercetum mixtum, 1st *Tilia* maximum, *Quercus*, *Pinus*, *Picea*.: Subzone R1 b is characterized by very high values of *Tilia*, high amounts of Cyperaceae and Polypodiaceae, some *Pinus* and small amounts of other tree and herb pollen. This basal part of the profile shows evidence of oxidation, probably the result of exposure to the atmosphere for a substantial period of time. Consequently, the assemblage may be biased towards grains that are most resistant to erosion.

LPAZ R 2 (130-100 cm): *Corylus*, *Alnus* (*Picea*, Qercetum mixtum, few *Taxus*): Zone R2 is characterized by a strong increase in *Alnus* accompanied by an expansion of *Corylus. Picea* has increased slightly, whereas *Tilia* shows the decline which has been observed during the *Corylus* expansion in other Reinsdorf profiles (Urban 1995a; 2007).

LPAZ R 3a (100-67 cm): 2nd *Tilia* maximum, *Picea-Carpinus* (*Alnus*, *Corylus*, very few *Abies*): During pollen subzone R 3a, *Tilia* recovers slightly and reaches a second maximum. This feature is observed in comparative profiles of Reinsdorf pollen diagrams from site 13 II.

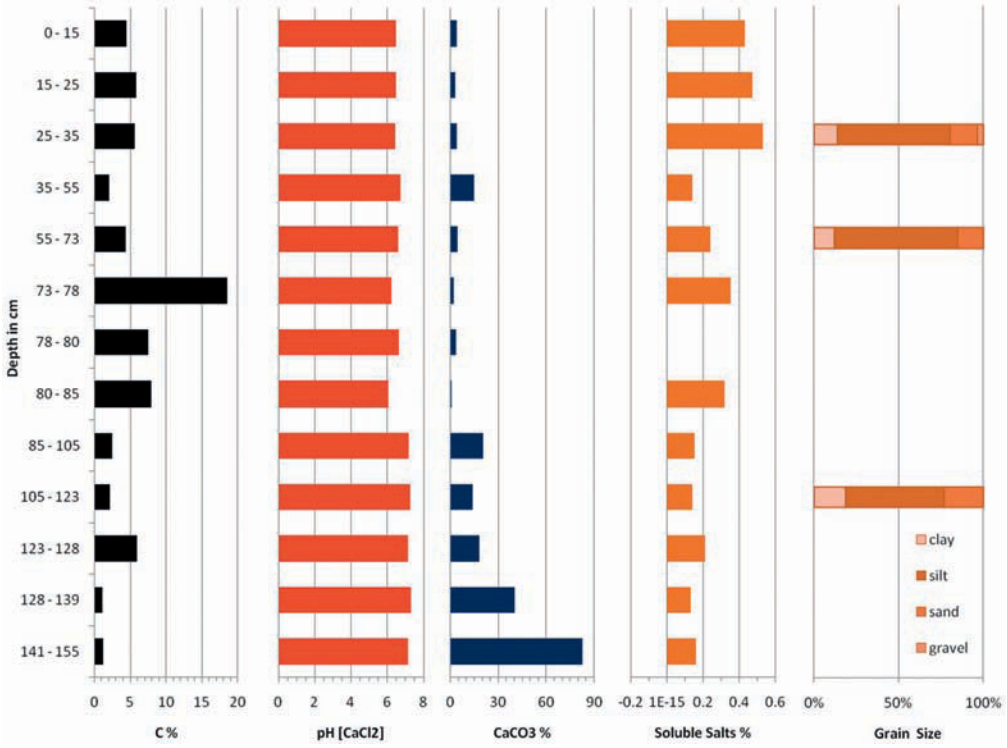

Fig. 8 Sedimentology of profile Schöningen 12 B, 1st archaeological horizon (92).

Subzone R 3a has been further divided into sub-subzones R $3a_1$ (100-82.5 cm) which is characterized by a decrease in *Alnus* und increasing *Pinus* and R $3a_2$ (82.5-67 cm) with a decline in *Tilia* but increases in *Abies*, Cyperaceae, Poaceae and other terrestrial herbs as well as Polypodiaceae.

LPAZ R 3b (67-0 cm): *Carpinus*, *Abies*, *Picea* (*Alnus*): Topmost subzone R 3b is dominated by *Carpinus* (to 11%), *Abies* (up to 8%) and *Picea* (around 7%) and contains occasional grains of *Pterocarya* and *Fagus*, the latter not shown in the diagram. *Alnus* is of minor importance whereas Ericaceae, Cyperaceae and *Sphagnum* as well as heliophilous terrestrial herbs are conspicuous and indicate a change in the local hydrological and light conditions. Massulae of *Azolla filiculoides* have been found in pollen subzone R3b as well as in all pollen zones of profile 12 B. It can be concluded that vegetation cover opened during that period of time. The first archaeological horizon situated between 50 cm and 30 cm can be assigned to the middle part of pollen subzone R 3b (**fig. 9**).

In summary, it can be stated that even though the lithology of profile B 12 varies between sandy, silty more or less organic, and carbonate rich silt and mud, no greater hiatuses have been observed, as the main characteristic pollen zones were detected. It is assumed that sedimentation rate was relatively low and might have varied, as seen in rapid taxa expansion during transitions. The profile spans part of the thermal optimum till the terminal *Carpinus-Abies-Picea* phase which is also recorded from profiles 13 A und 13 B (Urban 1995a) and recently investigated sequences from site Schöningen 13 II (Urban et al. 2011). Human occupation represented by the first archaeological horizon took place during the middle to late part of the terminal interglacial phase R 3b (**fig. 9**). Thieme et al. (1993) assigned this part of the Reinsdorf sequence to level II-1.

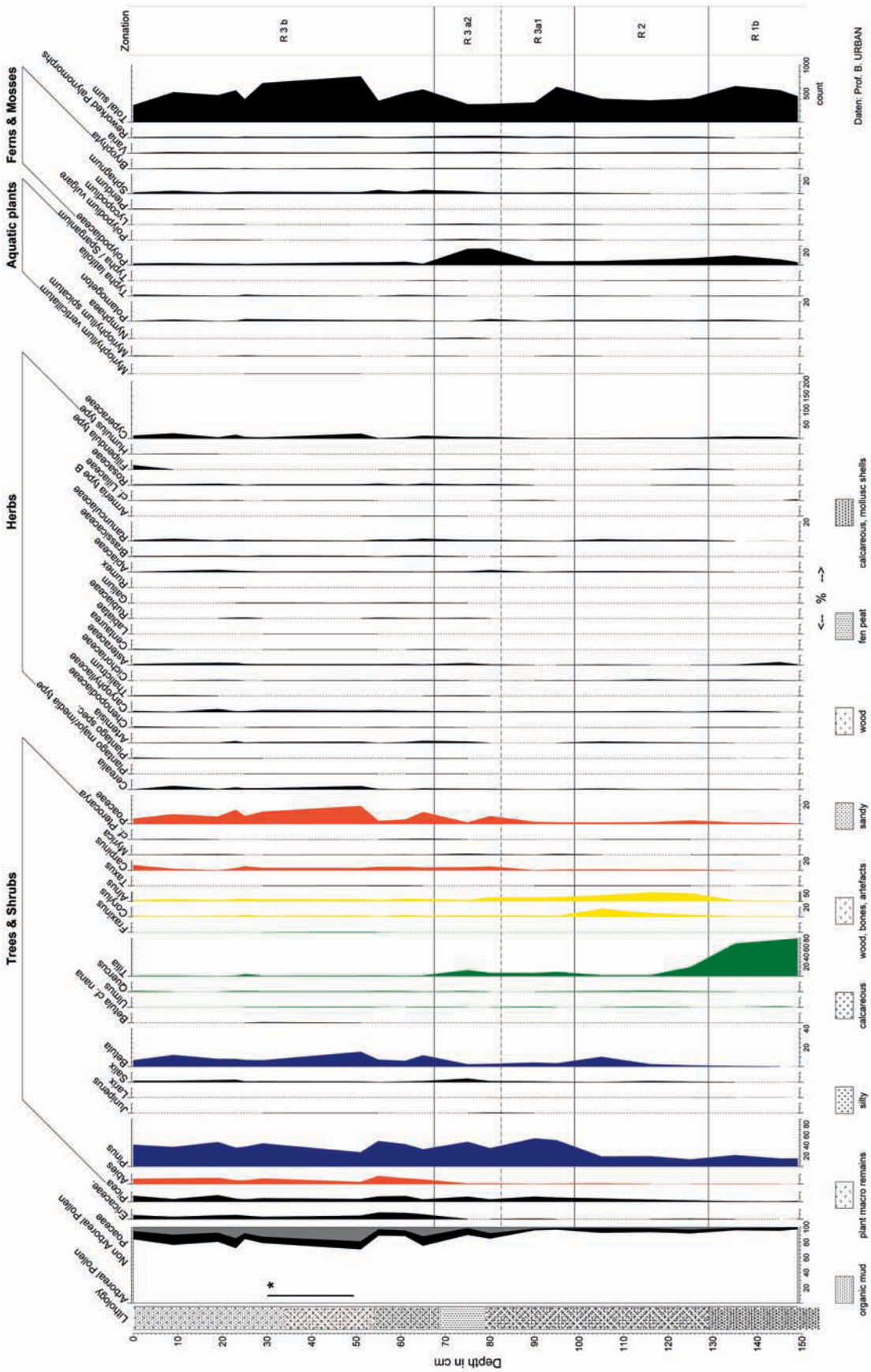

Fig. 9 Pollen diagram of profile Schöningen 12 B, 1st archaeological horizon (92). Asterix and bar are marking the level of the first archaeological horizon.

Urban 1995; Schöningen 13 II (96); Urban 2007, modified; Urban unpubl.	Schöningen 13 II (03), Urbanet al. 2011, Urban unpubl.	Profile 12 A (92), sample A1, profile 12 B (92); **figs 9. 11**	Profile 13 II K (92); **fig. 14**	Archaeological horizons at sites and profiles 12 A, (92) 12 B (92), 13 II	^{230}Th/U dated pollen zone/level Urban et al. 2011 Sierralta et al., this volume
LPAZ/ local subdivision	**LPAZ/ local subdivision**	**LPAZ/ local subdivision**	**LPAZ/ local subdivision**	**13 II – levels**	**age [ka]**
Poaceae, NAP, Betula,	RS II, in prep.			Level 13 II-5	
RI B: Pinus (Picea, Betula, Larix), Poaceae, NAP	RI 1d	level 12 A4	level 13 II K4 ?	hunting spears, level 13 II-4(c)	
(RS B)?: Juniperus, Poaceae, NAP	RI 1c (RS II ?)	?	?	?	
RI A: Pinus (Poaceae, Larix)	RI 1: (RI 1a-RI 1b)	level 12 A1-A2 A3	level 13 II K3 level 13 II K2	level 13 II-3	
RS A RS I1, I2: Poaceae,	RS I1, I2	A1	13 II K 1	level 13 II-2/3 2nd horizon 12 II-2	
R4/5: Pinus, Betula,(Alnus, Larix), Poaceae, Ericaceae	R 4/5	Hiatus?	Hiatus? R4/5		
R3b: Carpinus, Abies, Picea (Alnus) (Pterocarya, Fagus, cf. Celtis)	R3 b	R3 b	R3 b	1st horizon 12 II-1	290 ± 5
R3a: 2.Tilia phase, Picea, Carpinus (Alnus), Corylus, few Abies	R3a	R3a2 R3a1			
R2: Corylus, Quercus, (QM), Alnus (very few Taxus)	R2	R2			
R1b: QM, 1.Tilia phase, Quercus (Pinus, Picea) R1a: QM, Fraxinus, Tilia, Quercus, Pinus		R1b			
initial phases not recorded					

Tab. 1 Correlation of profiles Schöningen 12 B (92) and 12 A (92), Schöningen 13 II K (92), Schöningen 13-II (96) (Urban 2007) and Schöningen 13 II (03) reference profile (Urban et al. 2011) of the Reinsdorf sequence (Urban 1995) and position of archaeological horizons.

Profile Schöningen 12 A and sample 12 A1 of second archaeological horizon

From field observations it was visible that sequence 12 A discordantly overlay section 12 B (**fig. 4**). Section 12 A was assigned to level II-2 and II-3 of the Reinsdorf sequence. Sample A1 of archaeological horizon 2 was taken from basal organic rich (OC 12%), muddy calcareous (12% $CaCO_3$) silts of level II-2 of section 12 A (**fig. 4**).

The 460 cm long profile 12 A taken from above the second archaeological horizon starts at 0 cm defined as the top. It is generally characterised by alternations of strongly calcareous organic rich and organic poor silty, sandy mud containing molluscs and, at its base, small wood fragments. Sediments are nearly carbonate free at the bottom of the profile between 460 and 435 cm and the carbonate content increases

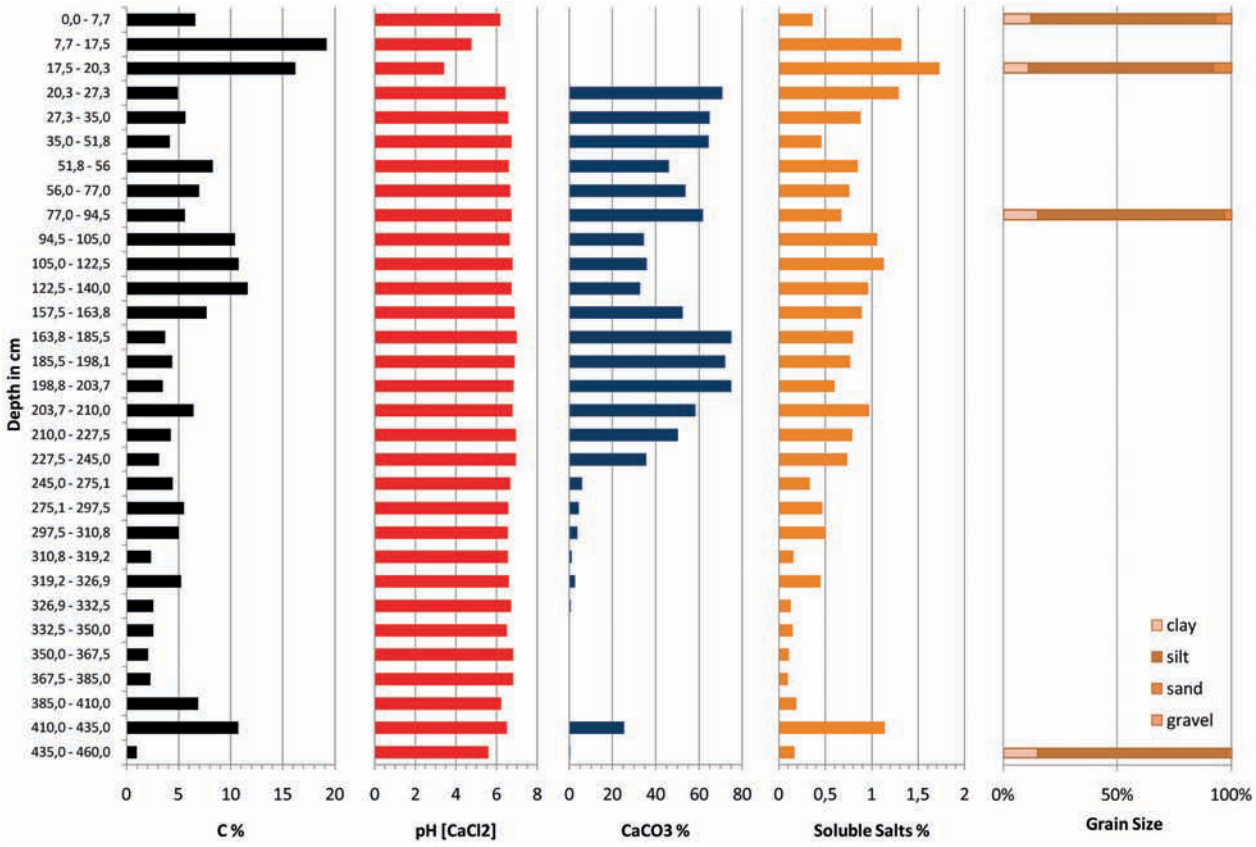

Fig. 10 Sedimentology of profile Schöningen 12 A (92).

up to 25% between 435 and 410 cm (**fig. 10**). The carbonate content drops again and then continuously increases up to ca. 6% from 410 to 245 cm (unclear). Organic carbon values range between 7% und 2.5%. From 245 up to 25 cm the sediment is extremely rich in carbonates (max. 75%) characteristic of the Characeae gyttja types described by Thieme / Mania (1993). Organic carbon varies at these depths between 3 and 11%. The top of the profile is then characterised by a peaty layer, which is carbonate free, consisting of ca. 19% organic carbon and enriched in soluble salts and acidified (**fig. 11**). Higher salt contents have frequently been found to occur in organic-rich peat and gyttja layers of the Pleistocene sequences in the Schöningen mine and are caused by post sedimentary processes of infiltration of saline groundwater under higher groundwater level.

Sample A1 (**fig. 11**, bottom) taken at the second archaeological horizon at the fire place is characterised by a complete lack of interglacial thermophilous tree pollen and is dominated (around 50%) by non arboreal pollen and by *Pinus* and *Betula*.

The succeeding profile 12 A has been subdivided into four major pollen zones 12 A1, 12 A2, 12 A3 and 12 A4 (**fig. 11**, top).

Zone 12 A1 (450-320 cm) shows slightly increased values for *Pinus* in comparison with sample A1 from the underlying horizon and the presence of *Alnus*, *Salix* and *Picea*. Ericaceae, *Sphagnum* and Polypodiaceae played a major role in the local swamp vegetation. Heliophilous terrestrial herbs including *Artemisia* and grasses reach in total between 15 and 35%. The swampy fen conditions are reflected by high amounts of *Sphagnum* and Ericaceae. The high amount of reworked mainly Tertiary palynomorphs indicates substantial erosional activity.

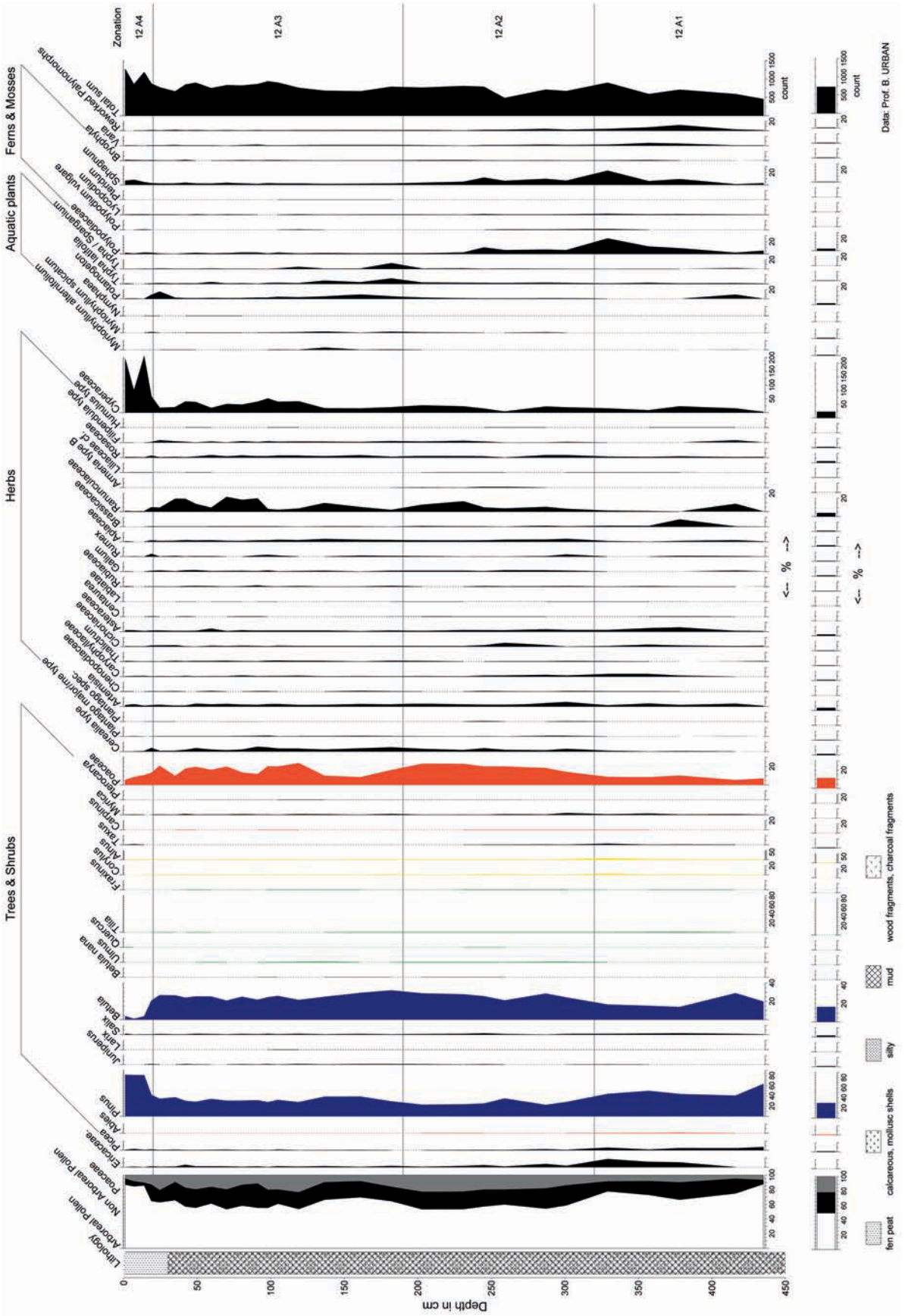

Fig. 11 Pollen diagram of profile Schöningen 12 A (92) and single sample Schöningen 12 A1 of 2nd archaeological horizon (fireplace).

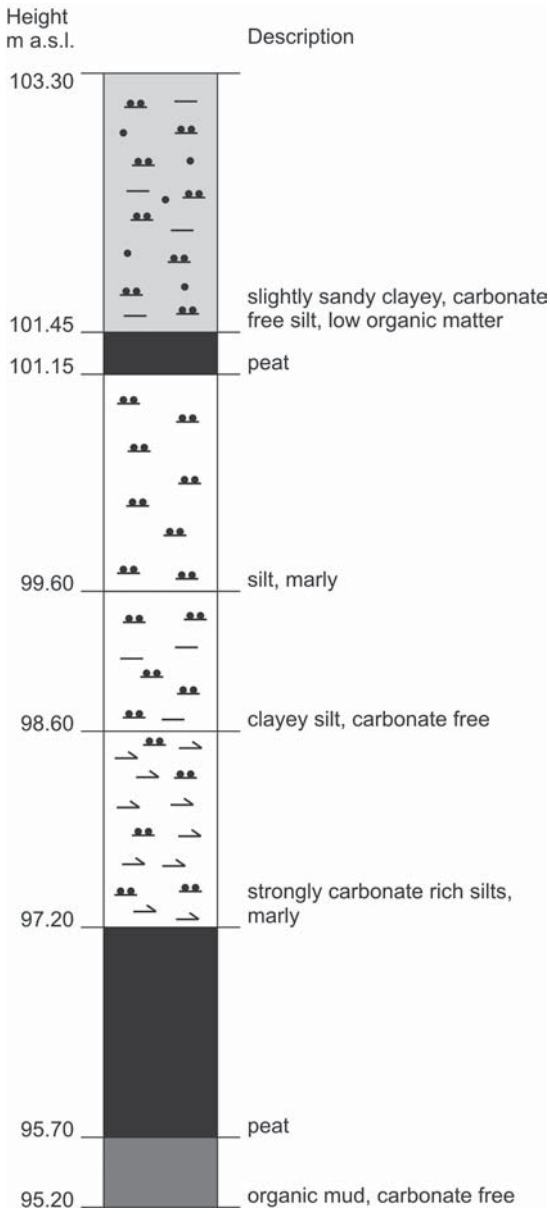

Fig. 12 Scheme of lithological setting of profile Schöningen 13 II K (92).

Zone 12 A2 (320-190 cm) is characterised by a strong increase of Poaceae (up to 25%) and heliophilous herbs and a temporary dominance of *Betula* over *Pinus.* The still swampy fen conditions are indicated by the occurrence of *Sphagnum* and Ericaceae in the lower to middle part of that pollen zone.

During Zone 12 A3 (190-20 cm) another small oscillation is recorded again by decreasing *Betula* (around 20%) and Poaceae (around 10%) and increasing *Pinus* values (to about 50%) between 190 cm and 130 cm. Increasing abundances of aquatic plant pollen like *Myriophyllum* spec., *Potamogeton* spec. and *Typha/Sparganium* in the lower part the zone, as well as the Characeae rich sediment type, point to spacious open water surface areas. The high amounts of pollen of Ranunculaceae in the upper part of Zone 12 A2 might predominantly derive from *Ranunculus aquatilis*, *Ranunculus acris* and from *Ranunculus sceleratus*. Seeds of those species, typical of aquatic and riverine vegetation respectively have been found to occur frequently in levels II-2 and II-3 at sites Schöningen 12 and 13 (Jechorek 1997; 2000; Jechorek et al. 2007).

The upper part of pollen zone 12 A3 is characterized by a rise in Cyperaceae and two peaks in the Ranunuclaceae (*Ranunculus acris* type) curve pointing to increasing terrestrialisation of the lake shore. Among the NAP, grasses are predominant with maximum values up to 23%, while the heliophilous terrestrial herb pollen sum (e. g. *Artemisia*, *Cerealia* type) oscillates around 20%.

Zone 12 A4 (20-0 cm) pollen assemblage, derived from the topmost peat layer, shows a strong increase in *Pinus* and a collapse of *Betula*. Terrestrialisation of the lakeshore is indicated in the uppermost part of the zone by reed species e. g. *Typha latifolia* and the strong increase in the Cyperaceae curve. As the peat is truncated, the further development of pollen zone 12A4 cannot be determined.

In summary it can be concluded that the landscape had turned into a more open woodland at the time of human occupation evidenced by the second archaeological horizon (sample A1). After pollen zone 12 A1, *Picea* and *Abies* disappeared and forest-steppes of boreal type with *Pinus* and *Betula* as the main woody taxa and *Larix*, *Juniperus*, grasses and heliophilous herbal taxa are indicative of zones 12 A2 and 12 A3. During the youngest recorded pollen zone 12 A4, the expansion of a denser pine forest is recorded.

Profile Schöningen 13 II K (92)

Sequence 13 II K discordantly overlaying Elsterian sediments has a comparable stratigraphic position to published profiles 13 A (13 II) and 13 B (13 II) (Urban 1995a).

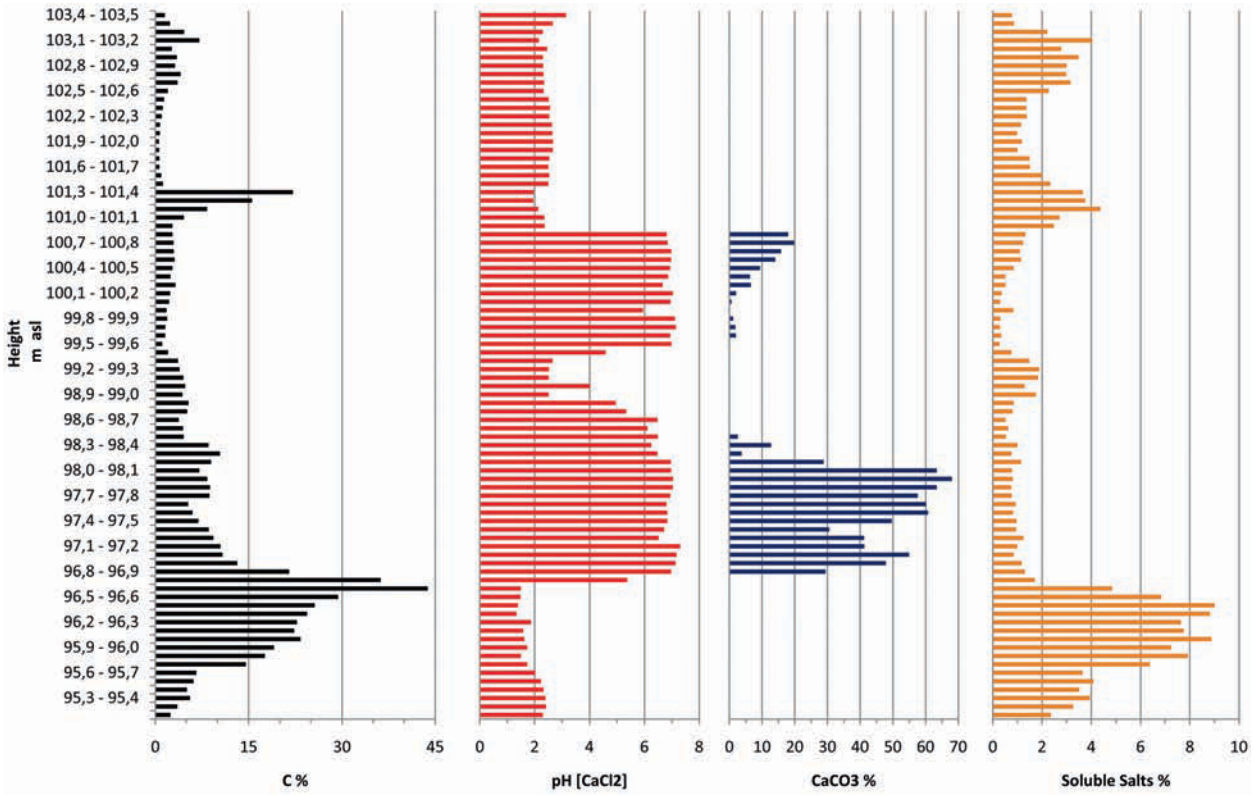

Fig. 13 Sedimentology of profile Schöningen 13 II K (92).

Profile Schöningen 13 II K (92) has the following sedimentological features (**figs 12-13**). Between 95.20 and 95.70 m asl, organic silty mud (max. 6% OC), which is carbonate free and contains up to 4% of soluble salts underlies peaty layers between 95.70-97.20 m asl. The peat itself is overlain by strongly carbonate rich (88% $CaCO_3$) travertine like silts consisting of 5% to 13% organic carbon from 97.20-98.60 m asl. Sediment layers at 98.60-99.60 m asl, are composed of carbonate free clayey silts with medium organic carbon contents ranging between 2 and 5%. From 99.60 to 101.15 m asl, the OC content of the slightly marly silts is decreasing. A decomposed peaty layer is intercalated between 101.15 and 101.45 m asl, which is again carbonate free and consists of up to about 20% organic carbon. The top of the profile is made up of slightly sandy clayey, carbonate free silt with marginally higher organic contents between 101.45 and 103.30 m asl.

The pollen diagram has been divided into five pollen zones (**fig. 14**):

The lower most pollen zone Zone R 3b 4/5 (95.25-95.70 m asl) is characterised by *Pinus*, *Alnus* and *Betula*. The values of the taxa *Picea*, *Ulmus*, *Tilia*, *Carpinus* and *Abies*, which are all present with low amounts at the base, are approaching zero percentage towards the upper boundary of the zone. Cyperaceae and Ericaceae as well as Sphagnum spp. indicate a swampy environment. Beside the authochtonous sporomorphs, high amounts of reworked pollen and spores have been found in the uppermost samples. The late interglacial pollen composition can be correlated with zone R4/5 in other Reinsdorf pollen diagrams.

The subsequent Zone 13 II K1 (95.70-96.25 m asl) is characterized by a strong increase of Poaceae (60%), *Artemisia* and other heliophilous herbs. The *Pinus* curve has decreased to 12-24%, whereas the curve of *Betula* oscillates around 15-20%. High amounts of Polypodiaceae point to increasing humidity. This zone,

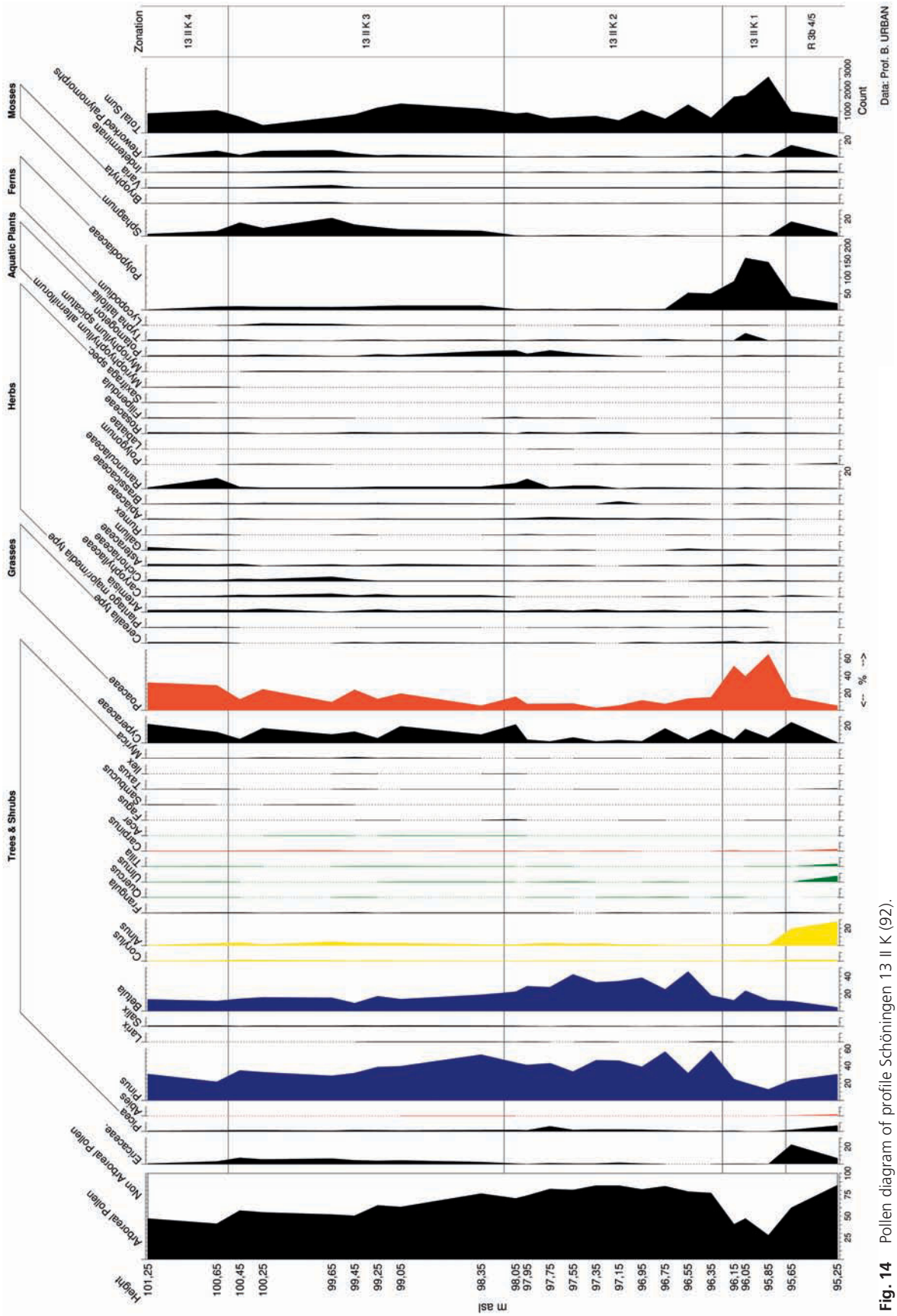

Fig. 14 Pollen diagram of profile Schöningen 13 II K (92).

which is developed in organic peat facies, indicates increasing terrestrialisation of the local environment. Similar features have been observed in other pollen diagrams of the Reinsdorf sequence and allow correlation with Reinsdorf Local Pollen Assemblage Zone (LPAZ) RS I (Urban 2007; Urban et al. 2011).
Zone 13 II K2 (96.25-98.15 m asl) is still developed in organic telmatic facies up to 97.20 m asl whereas the upper most part is characterized by a marly, strong calcareous sediment. It displays new expansions of *Betula* and *Pinus* and decreases of grasses and herbaceous taxa. The curves of *Betula* and *Pinus* alternate throughout this zone while *Alnus* and *Picea* pollen are restricted to the upper part of the zone. The curves of Cyperaceae and Poaceae have dropped while amounts of *Potamogeton* and of probable aquatic Ranunculaceae increase in the upper part of the zone pointing to local open water conditions.
During Zone 13 II K 3 (98.15-100.55 m asl) *Pinus* achieves values of between 30 and <50%, *Betula* oscillates around 15%, while values for Poaceae and Cyperaceae as well as those of *Sphagnum spp.* and Ericaceae have strongly increased. The spectrum of heliophilous taxa becomes more diverse.
Towards the upper part of Zone 13 II K4 (100.55-101.25 m) the curve of *Pinus* declines whereas NAP taxa, including Poaceae, *Artemisia*, *Galium*, Asteraceae, Cichoriaceae and Ranunculaceae, increase up to 50%.
In summary, the diagram represents later parts of the Reinsdorf interglacial; the terminal *Pinus*, *Betula*, *Alnus* and *Picea* phase can be correlated with pollen Zone R 4/5 of reference diagrams e. g. Schöningen 13 II (96) (Urban 2007; Urban et al. 2011) and a climatic deterioration reflected by zone 13 K2, which most probably can be correlated with the LPAZ RS I (**tab. 1**). The subsequent zones are characterized by higher values of *Betula* and *Pinus* and an almost total lack of thermophilous tree taxa, only *Alnus* and *Picea* occurring occasionally with low values.

DISCUSSION

The palynological findings and age determinations are discussed below with emphasis on the nature and correlation of the Reinsdorf sequence.

Schöningen (Cycle III), northern mining area

The sequence later termed channel, respectively cycle III (Mania 1995; 1998) is composed of silty muds and peats and represents the Schöningen Interglacial (Urban et al. 1991b; Urban 1992; 1995a). The pollen assemblages indicate a warm climate and are generally characterised by high percentages of *Pinus* and *Tilia* with some *Quercus*. High amounts of *Alnus* were found almost throughout the entire profile. A *Carpinus* phase with *Picea* occurs near the end of the warm period, while *Abies* is absent, apart from an occasional grain. Massulae of the water fern *Azolla filiculoides* are abundant in the *Alnus*-rich parts of the sequence. The Schöningen Interglacial is succeeded by the Elm A Stadial which is followed by two temperate periods, the Büddenstedt I and II Interstadials, revealing *Pinus-Betula* forests. The interglacial and stadial-interstadial sequence of channel III (cycle III) is overlain by glaciofluvial sands and till of the first Saalian ice advance (Drenthe Stadium). Based on the pollen record, correlation has been made with the Wacken (Menke 1968; 1980) and Dömnitz (Erd 1970; 1973) Interglacials and Hogeveen Interstadial (Zagwijn 1973) (**fig. 1**) by Urban et al. (1991b) and Urban (1995a; 2007). A review of age determinations of peat of the Schöningen Interglacial, which gave uncorrected $^{230}Th/^{234}U$ ages of 180 and 227 ka (Heijnis 1992), is presented in detail in Sierralta et al. (this volume).

Holsteinian (Cycle I)

During the initial phase of the brown coal excavations, limnic and telmatic deposits of a broad channel (later termed Cycle I; fig. 2) overlying the Elsterian sequence have been exposed. Based on its characteristic pollen assemblages with Abies reaching up to nearly 50% and Pinus, Picea and Pterocarya well represented (Urban 1997), Cycle I layers have been assigned to late parts of the Holsteinian Interglacial and correlated with other sites in North western Germany (amongst others Munster-Breloh, Heidekreis: Müller 1974; Hamburg-Dockenhuden: Linke / Hallik 1993; Bossel, Lkr. Stade: Müller / Höfle 1994), by Urban et al. (1991b; Urban et al. 2011) and Urban (2007). A strong cooling is recorded by a significant increase in herbaceous pollen including grasses during the following Buschhaus A Stadial, which is considered to mark the onset of the Saalian Complex sensu lato (penultimate glacial-complex) (INQUA SEQS, 1992). That stadial period is followed by a twofold temperate boreal phase, the Missaue I and II Interstadials, while Buschhaus B Stadial had a steppic character. It is followed by another temperate phase, Interstadial SU A, with Pinus being the dominant tree genus.

Cycle I sediments from the southern mining area of the Schöningen open-cut mine (fig. 3) underlie gravel and channel II (Cycle II) sediments revealing evidence for a boreal type of open landscape vegetation (Urban, unpublished) where another fire place of Homo erectus (Thieme 1995; 2007) was excavated. As the pollen spectra contain pollen of warm loving interglacial taxa (*Abies*, *Carpinus*, *Taxus*, *Fagus*) with low amounts and reworked pollen and other microfossils (e. g. *Symplocos*, Dinoflagellates), a correlation with other sequences remains open so far. The mammalian fauna of the excavated site (van Kolfshoten 1995; van Kolfschoten et al. 2007) is mainly composed of elephant, (cf. M. trogontherii) bison, horse and red deer. Richter (1998) dated a burned flint of the fire-place of those Cycle I sediments by thermoluminescence (TL) to 450 ± 40 ka. Recent palynological results of the Cycle I deposits (Schöningen 13 I) of the southern mining field and those of site 13 I DB show great similarities with the Holsteinian deposits of the northern mining field (Urban, unpublished).

Reinsdorf (cycle II) interglacial pollen assemblages of the southern mining area, though having certain similarities, differ in many aspects from those of comparable pollen zones of Holsteinian sediments of the northern mining field. As an example, *Abies* is present with high values between 30% and 50%, *Picea* with 10-15%, while *Carpinus* ranges between 1% and 5% in both mere peat and limnic-telmatic deposits of the Holsteinian in the northern mining field. In the Reinsdorf sequence of the southern mining field the *Carpinus-Abies* phase is generally characterised by *Abies* values below 10% (max. 15%), whereas *Carpinus* can reach up to 30% (Urban 1996a). The joint appearance of single grains of cf. *Pterocarya* and very scattered occurrences of *Fagus* in late phases of both interglacials seems a significant tool for correlation as the occurrence of *Pterocarya* is often taken as a marker for the Holsteinian (see above). Hence it has to be noted that the occurrence of *Pterocarya* in the Schöningen profiles is not restricted to a distinctive pollen zone, either to the Reinsdorf or to Holsteinian deposits of the northern mining area only. *Pterocarya* pollen has also been found in Pleistocene horizons of different stratigraphic positions in mine Schöningen, which often consist of reworked Tertiary and Early Pleistocene fossils, including pollen and dinoflagellates. The stratigraphic value of this marker for deposits of the manifold glaciated North European lowland, where sediments often consist of considerable amounts of reworked sporomorphs, is therefore questioned by Meijer / Cleveringa (2009). This is supported by our observations of the occurrences of *Pterocarya* pollen in Pleistocene sequences of mine Schöningen, each of which demands careful interpretation. Other co-occurring marker species of Middle Pleistocene Central European interglacials are *Fagus*, *Taxus*, *Celtis* and *Azolla filiculoides*. Grüger et al. (1994) found evidence of those taxa in forest phase 3 of drill core sediments of Göttingen-Ottostraße. Correlation of this *Carpinus* und *Abies* rich interglacial phase with sequences of pit

Nachtigall, which has recently been Uranium/Thorium dated, suggest a MIS 7 age of those warm temperate forest phases (Waas et al. 2011).

Reinsdorf (Cycle II)

The sediment sequence of Cycle II contains a series of five levels (levels 1-5, cycle II-1 to cycle II-5) represented by peat and organic, silty and calcareous muds, in places extremely rich in molluscs (Mania 1998; 2007). These lacustrine sediments have been found to occur at archaeological sites Schöningen 12 and 13 (Thieme et al. 1993; Thieme / Mania 1993; Thieme 1996; 1997; 1999; Urban 1999). Urban (2007) has described at least 13 local pollen assemblage zones. The vegetation succession of the Reinsdorf sequence described by LPAZ (see as well Urban 1995a) is described as a two-folded Quercetum mixtum-phase LPAZ R1a with *Tilia*, *Fraxinus* predominant, and by LPAZ R1b with a first *Tilia* phase, which is followed by LPAZ R2, the *Corylus-Quercus*-(QM)-*Alnus* (few *Taxus*) zone. A second *Tilia* maximum is characteristic for the *Picea-Carpinus*-(*Alnus*, *Corylus*) phase of LPAZ 3a and followed by the *Carpinus-Abies-Picea* (*Alnus*) LPAZ R3b and a *Pinus-Betula*-(*Alnus*, *Larix*)-Ericaceae-Zone, LPAZ R4/5. The water fern *Azolla filiculoides* occurs frequently during the Quercetum-mixtum-phase though also in younger zones. Occasional grains of *Fagus* and *Pterocarya*, though occurring with single grains in other layers of Schöningen sequences (Urban et al. 2011), have been found in LPAZ 3b/4. The interglacial ends with an opening of the boreal woodland and a strong increase of grasses, terrestrial herbs and local expansion of Ericales during LPAZ RS I1 and RS I2, followed by open forest- steppes of boreal type (RI A and B after Urban 2007) represented mainly in peat sediments.

Correlation of pollen zones of the analysed profiles Schöningen 12 B, 12 A, and single sample A1 and of profile 13 II K to other sections of the Reinsdorf sequence are presented in **table 1**.

The first archaeological horizon of site 12 B (level II-1, base of II-2 respectively) (Thieme 1996; 1997; 1999), can be assigned to the *Carpinus-Picea-Abies* zone (**fig. 9; tab. 1**) and correlated with LPAZ R3b after Urban (1995a; 2007). Level II-1 is characterised by elements of slightly open deciduous and mesophilous mixed deciduous forests as demonstrated by karpological findings (Jechorek 2000; Mania / Mai 2001; Jechorek et al. 2007).

Pollen zone R3b, which contains occasional grains of Pterocarya and Fagus significant for Holsteinian pollen zones 6 after Erd et al. (1987) and pollenzone XIII (Müller 1974), has recently been ^{230}Th/U dated (Sierralta et al. this volume). More results of this 16 m reference profile of the Reinsdorf sequence in comparison to other interglacial pollen spectra of mine Schöningen are discussed at length in Urban et al. (2011).

The second archaeological horizon (**fig. 11; tab. 1**) at the fire place is characterized by an open pine, birch woodland rich in grasses and further heliophilous herbs. The pollen spectrum might at best be placed at the base of local zones RS I1, I2 which is dominated by Poaceae, NAP and among the 50% tree pollen by *Betula*, *Pinus* and *Salix* accompanied by *Juniperus*.

The Schöningen 13 II K profile consists of late interglacial pollen spectra (13 II K1) and the transition to an open environment evidenced by a strong increase of grasses, terrestrial herbs and Ericales and a pronounced decrease of arboreal pollen (pollen zone 13 II K2), which most probably correlates with Reinsdorf LPAZ RS I (Urban 2007) (**fig. 14; tab. 1**). The subsequent pollen zones 13 II K 3-K 4, sample A1 of the second archaeological horizon and following zones 12 A1-A3 of profile 12 A show great similarities with respect to the palaeoenvironmental conditions and seem to reflect a climatic amelioration though of minor intensity following the thermal decline. Cool boreal conditions are confirmed by malacozoological analyses (Thieme et al. 1993, Mania in: Thieme / Maier 1995). The entire 12 A sequence has been attributed to level

II-2, II-3 respectively by Thieme et al. (1993), which would most probably imply that the peat of pollen zone 12 A4, which is not reproduced in profile 13 II K, is reflecting parts of levels II-3 and II-4 of the Reinsdorf sequence RI A and B (Urban 1995; 2007).

Heijnis (1992) and Heijnis / Urban (1995) published the first ^{230}Th/234U uncorrected age of approx. 320 ka from peat of the Reinsdorf sequence (peat samples of profiles 12 A, 12 B, 13A II were dated). A 16 m profile covering the biostratigraphic units of the Reinsdorf sequence at the hunting spear excavation site Schöningen 13 II (2003) still under detailed investigation has recently been dated and palynologically investigated in a preliminary fashion. The first thermal ionisation mass spectrometry (TIMS) ^{230}Th/U dating of peat taken from this profile has provided new evidence for the age of the Reinsdorf sequence (Urban et al. 2011), (**tab. 1**). The ages range from 280-343 ka with a mean isochron age of 290 ± 5 ka. Details are given by Sierralta et al. (this volume).

CONCLUSION

Palynological analysis of profiles from the archaeological site Schöningen 12 (92) and 13 II K (92) reflect full and late interglacial phases of the Reinsdorf interglacial and the beginning of the subsequent climatic deterioration. New ^{230}Th/U dating results (Sierralta et al., this volume) ranging from 280-343 ka initially suggest a correlation of Reinsdorf pollen subzone LPAZ 3b, which is the corresponding level of the first archaeological horizon, with MIS 9 substages. Though the palynological investigations of those profiles are still ongoing, based on the ^{230}Th/U dating a correlation of the Reinsdorf sequence with Holsteinian deposits dated at the type site of Bossel (Geyh / Müller 2005; 2007) has to be taken into consideration. Such a correlation would imply that the Reinsdorf interglacial represents a regionally highly variable form of the Holsteinian sensu strictu (Urban et al. 2011) and leads to some reconsiderations of previous attempts at correlation, which need to take into account the results of the multidisciplinary research in the open mine Schöningen.

ACKNOWLEDGEMENTS

We are very indebted to Dr. Hartmut Thieme, the archaeological excavator of the Schöningen sites, for his sampling and provision of sediments as well as for his support during field work, fruitful and stimulating discussions, advice and financial support. We thank Christiane Hilmer for valuable help with laboratory treatment of the samples and soil analyses and Barbara Albrecht for her assistance with the palynological work. We are very thankful to Mario Tucci and Alexander Kunz who helped to draw the graphs and figures. We finally thank Peter Kershaw for critically reading the manuscript and the two reviewers for their valuable advice.

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ABSTRACT / ZUSAMMENFASSUNG

Neue palynologische Befunde und Korrelation der altpaläolithischen Fundstellen Schöningen 12 B und 13 II, Tagebau Schöningen

Das Pleistozän im Tagebau Schöningen baut sich aus einer Vielzahl interstadialer und interglazialer limnisch-telmatischer, travertinartiger, glazigener und äolischer Ablagerungen und Böden auf. In diesem Beitrag stellen wir insbesondere palynologische Untersuchungsergebnisse der Reinsdorf Sequenz (Zyklus II) aus Profilen paläolithischer Fundhorizonte unter Berücksichtigung neuer ^{230}Th/U-Datierungen vor. Die vorliegenden Befunde lassen eine klare Korrelation der Profile der archäologischen Seeufer Vorkommen 12 II und 13 II zu. Die ^{230}Th/U-Alter spätinterglazialer organischer Sedimente mit einer Spannbreite von 280-350 ka legen eine Korrelation der Reinsdorf Sedimentabfolge mit der Marinen Sauerstoffisotopenstufe 9 nahe.

New palynological evidence and correlation of Early Palaeolithic sites Schöningen 12 B and 13 II, Schöningen open lignite mine

The Pleistocene of the Schöningen lignite mine is represented by various interglacial and interstadial peat and limnic sediments, travertine tuff, soils, tills and fluvioglacial and loess deposits. This paper discusses palynological investigations of sections of the Middle Pleistocene Reinsdorf sequence in relation to Lower Palaeolithic archaeological horizons and new ^{230}Th/U ages. There is significant evidence for a correlation of the archaeological lake margin sites 12 B and 13 II. The ^{230}Th/U ages of late interglacial organic layers range from 280-350 ka suggesting a correlation of the Reinsdorf sediment succession with Marine Isotope Stage (MIS) 9.