28. Interglacial Pollen Records from Schöningen, North Germany

Brigitte Urban

University of Lüneburg, Campus Suderburg, Herbert-Meyer-Str. 7, 29556 Suderburg, Germany

ABSTRACT

The Pleistocene sequence of the Schöningen lignite mine contains a number of interglacial and interstadial limnic and peat deposits, travertine tuff, soils, tills and fluvioglacial as well as loess deposits. There is evidence of four interglacials younger than the Elsterian glaciation and preceding the Holocene. The complex Pleistocene sequence contains six major cycles. The sequence begins with Late Elsterian glacial and interstadial deposits preceding the Holsteinian, followed by the Reinsdorf and Schöningen interglacials, which represent the pre-Drenthe (Early Saalian Stadial) period. A pedocomplex developed in alluvial loess, younger than the Drenthe Stadial of the Saalian glaciation, is succeeded by a sequence of soft travertine and peat representing Eemian marine isotope stage 5e (MIS 5e) and MIS substages 5d, 5c. Channel sediments provide evidence of the Weichselian late glacial and the Holocene.

The Schöningen pollen record of MIS 5 and tentative correlatives of MIS 7, 9 and 11 as well as temperate interstadials of Late Elsterian and (intra) Saalian (s.l.) age are discussed and compared with other pollen records of North Germany, Western and Central Europe. Detailed pollen evidence for the Reinsdorf sequence, which is significant for its Lower Palaeolithic sites, including stadials and interstadials, is a major focus.

Keywords: Pleistocene, palaeobotany, palaeoclimate, $^{230}Th/^{234}U$ dating, interglacials

28.1 INTRODUCTION

The Pleistocene sequence of Schöningen (Lower Saxony, Germany) provides a key link between unglaciated and glaciated areas in Western Central Europe (Fig. 28.1). The complex Pleistocene sequence is of significance for the subdivision of the glaciated younger Middle Pleistocene part of Western Central Europe (Thieme *et al.*, 1987; Urban *et al.*, 1988, 1991a, 1991b; Urban 1995a, 1995b, 1996a, 1996b, 1999, 2002) and for archaeological evidence of early human occupation by *Homo erectus* (Thieme *et al.*, 1987, 1992, 1993; Thieme and Maier, 1995).

The investigations have focussed on exposed Quaternary deposits that are considered to span much of the last 500 000 years. The investigations occurred as excavation fronts progressed during mining of the underlying Eocene lignites. The Quaternary deposits are composed of various types of sediments including peaty, muddy and silty layers from former swamps, lakes, peat bogs and river flood plains, as well as hydromorphic soils 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.

The classical Holsteinian interglacial underlain by Elsterian glacial and Late Elsterian interstadial sediments was followed by a cold climatic deterioration interrupted by several temperate phases, the Mißaue 1, Mißaue 2 and SU A interstadial (Urban *et al.*, 1991b). This cycle was later termed Channel 1 (Fig. 28.2) (Mania, 1998). A series of six such cycles of interglacial or

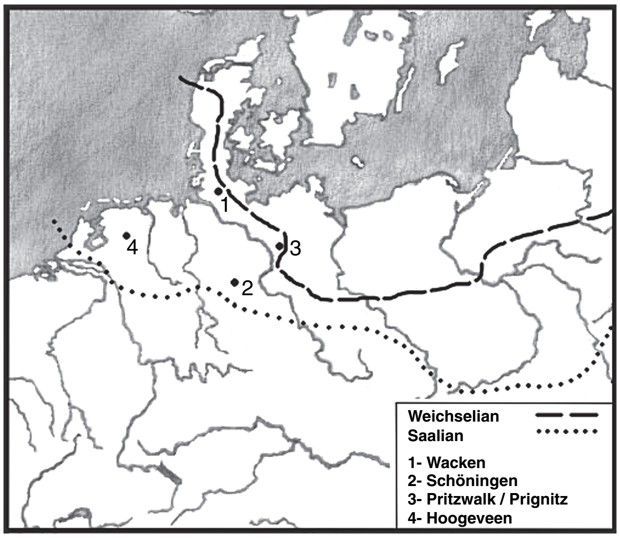

Fig. 28.1 Maximum extension of Saalian and Weichselian ice sheets. Locations of Hoogeveen, Wacken, Schöningen and Pritzwalk / Prignitz (Dömnitz).

interstadial and early glacial deposits in depressions (channels) have been identified, all considered to be climatically induced. Channel II (Reinsdorf Interglacial) and Channel III (Schöningen Interglacial) represent warm climatic periods older than the Saalian ice advance. Channel IV, a pedosequence of pseudogleyic, alluvial loess, which has not yet been fully studied (Altermann, in preparation), overlies the older Saalian till (Drenthe stadium). The sediment in Channel V is a sequence of travertine, silts and peat, which has been correlated to the Eemian and to stage 5e of the marine isotope record (Urban *et al.*, 1991a; Heijnis, 1992; Heijnis and Urban, 1995). Early Weichselian silts composed of loess, solifluction layers and fluvial deposits mark the onset of strong cooling. Late Weichselian Alleröd peat with the Laacher See volcanic tuff layer and Younger Dryas silt had been identified underlying the Holocene sequence (Channel VI) (Urban *et al.*, 1988) (Fig. 28.2).

There is still debate about the stratigraphic position and correlation of the Reinsdorf and the Schöningen interglacials and major interstadials found in Schöningen with other pollen records and the marine

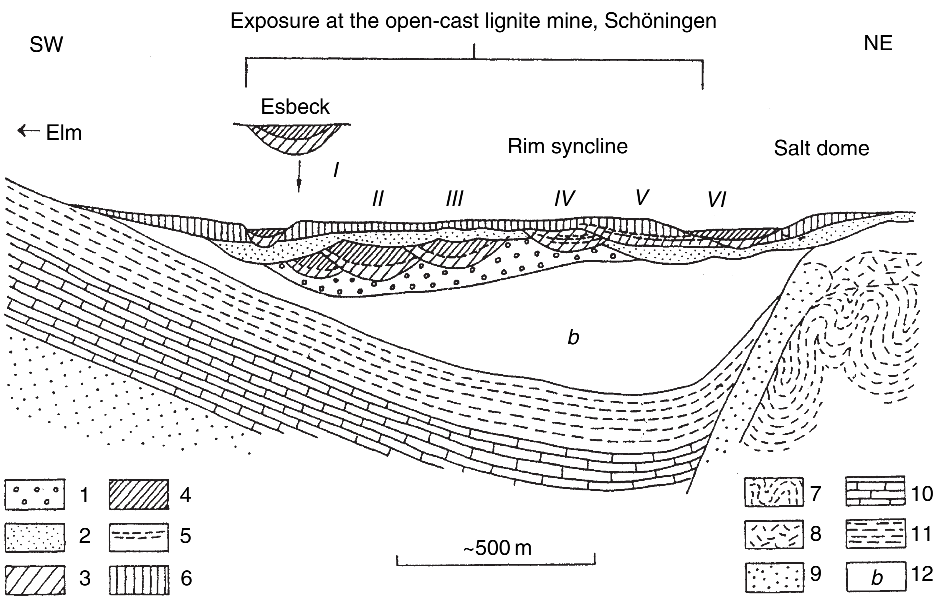

Fig. 28.2 Schematic section through the Quaternary sedimentary cycles I–VI (modified after Mania 1995; Mania, 1998; Thieme, 1997). The thickness of the geological deposits is not shown to scale. The Quaternary sediments reach a maximum thickness of ca. 45 m in the Esbeck mining field (Urban et al.*, 1991b). The actual distance between cycle VI Channel filling and the salt dome is about 2 km (this distance is not shown to scale). 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 (= b), Tertiary deposits.*

istotope statigraphy. Of particular interest is the age and stratigraphic position of the Reinsdorf sequence which contains archaeological horizons with wooden throwing spears that are thought to be the oldest hunting weapons so far discovered (Thieme, 1996, 1997, 1998, 1999).

28.2 OPEN MINE ESBECK/ SCHÖNINGEN

The halokinetic depression of Schöningen formed on the flanks of the Helmstedt-Staßfurt Zechsteinian salt dome and was filled with thick limnic and marine sequences during Eocene times. At Schöningen, these Tertiary strata are unconformably overlain by Quaternary sediments and soils of Middle and Late Pleistocene and Holocene age (Fig. 28.2).

Mania (1998) described the Quaternary halokinetic processes as persisting mainly during interglacial periods, when shallow depressions, the channels, were formed, trending predominantly from northwest to southeast, corresponding to the trend of the salt dome. These channels have been filled with thick limnic, telmatic sediments or pedocomplexes (Fig. 28.2). Fennoscandian glaciers advancing from the northeast filled the depressions with glacial deposits. The study area has been covered twice by a Fennoscandian ice sheet, first during the Elsterian, the oldest ice advance of Northern Germany and Central Europe, and then the later Saalian advance (Fig. 28.1), and it was unglaciated during the last glaciation (Weichselian, MIS 4-2).

28.2.1 Elsterian

The oldest Pleistocene sediments are glaciofluvial sands of an early Elsterian ice advance, which are overlain by two Elsterian tills. The younger till is capped by rhythmites, which in turn are overlain by three interstadial layers, formed in shallow basins, locally named Offleben 1, Offleben 2 and Esbeck (Urban *et al.*, 1988, 1991b; Elsner, 2003; Wansa, unpublished data) (Fig. 28.3). During the Offleben 1 and Offleben 2 interstadials, a boreal forest type prevailed, mainly dominated by birch, pine and spruce and locally elder in the late phases of a growing fen.

The youngest of the investigated interstadials, the Esbeck Interstadial (Fig. 28.4), which is documented by nearly 3 m of organic mud and peat, is characterised by an early phase of open tundra-steppe with *Juniperus*, *Salix*, *Pinus*, *Betula* and some *Alnus* and *Picea*, followed by a succession of *Juniperus* and *Salix* during the *Betula* Zone (ESB3) and the expansion of *Pinus* and *Picea* during the local fen growth Zone ESB4, which is characterised by the occurence of *Larix* pointing to continental climatic conditions.

Possibly three lithologically corresponding Late Elsterian interstadial phases have recently been identified in core sediments taken in the neighbouring Aller valley near Morsleben (Saxony-Anhalt), an exploration site for nuclear waste disposal, by Elsner (2003).

28.2.2 Holsteinian (Cycle I)

During the initial phase of the brown coal excavations, limnic and telmatic deposits of a channel (Cycle I, Fig. 28.2) overlying the Elsterian sequence have been exposed adjacent to the Eemian Channel (Cycle V) and stratigraphically well positioned in relation to the Holocene (channel and Cycle VI) (Fig. 28.5).

Because of its palynological composition in comparison with other sites in NW Germany (amongst others Munster-Breloh: Müller, 1974b; Hamburg-Dockenhuden: Linke and Hallik, 1993; Bossel: Müller and Höfle, 1994), Urban *et al.* (1991b) assigned Cycle I to late parts of the Holsteinian interglacial. The terminal phase of the Holsteinian (Fig. 28.3) contains *Abies*, *Pinus*, *Picea* and *Pterocarya* as well as the water fern *Azolla filiculoides*, which is restricted to Early and Middle Pleistocene interglacials in

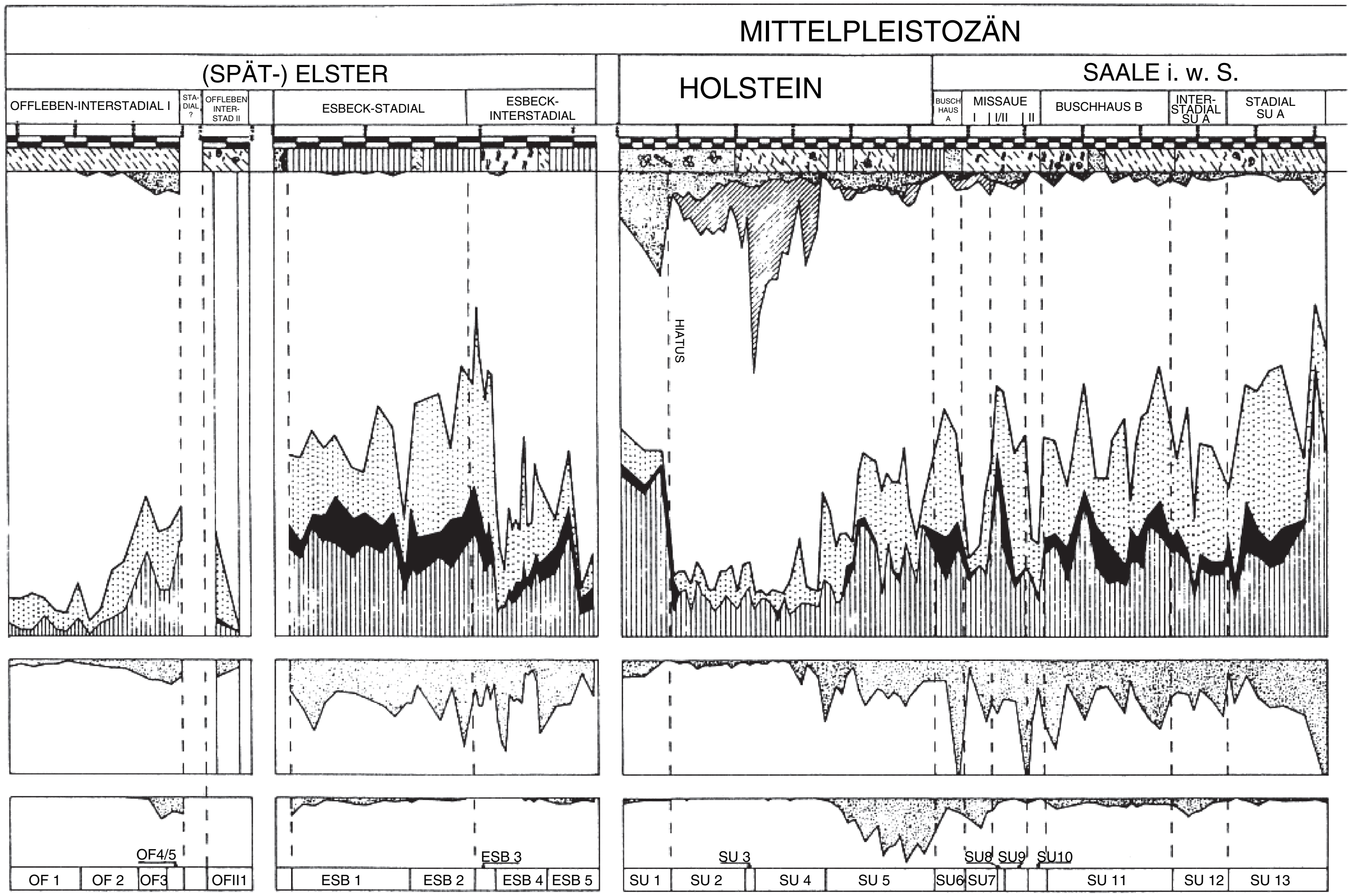

Fig. 28.3 Elsterian and Holsteinian pollen sum curves.

Fig. 28.4 Limnic telmatic sediments of Late Elsterian Esbeck interstadial overlaying silt and niveofluviatile sand.

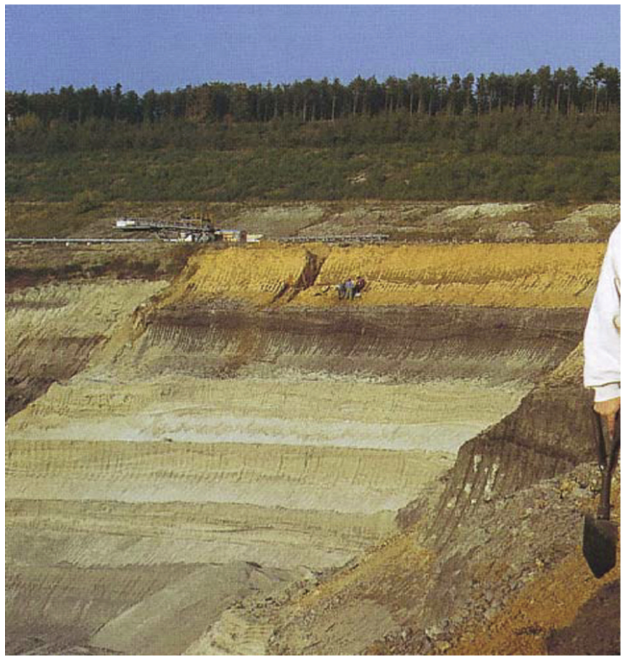

Fig. 28.5 Left (position of mining device): Cycle VI (late glacial and Holocene deposits composed of peat, alluvial loess, Tschernozem). Middle Part: Cycle V (Eemian calcareous tuff and peat and Early Weichselian loess palaeosol sequence). Right: Channel I (Holsteinian and successive early Saalian interstadials: peat and silty basin deposits). Photo from Thieme and Maier, 1995 (modified).

Central Europe (Urban, 1997). A strong cooling is recorded by a significant increase of *Artemisia* and 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 phase, the Missaue I and II interstadials, characterized by pine, birch and some spruce. Buschhaus B Stadial had a steppe environment with dwarf shrub tundra and was followed by another temperate phase, interstadial SU A, with *Pinus* being the dominant tree genus (Fig. 28.3). Cycle I sediments are not recorded from the southern mining area of the Schöningen open-cut mine, but here evidence for a Late Elsterian fire place of *Homo erectus* has been found, which is situated discordantly below gravel and Channel II (Cycle II) sediments. Richter (1998) dated a burned flint of the fire place by thermoluminescence (TL) to 450 ± 40 kyr.

28.2.3 Reinsdorf (Cycle II)

Channel II (Figs. 28.2, 28.7) is filled by sediments of the Reinsdorf Interglacial, a new biostratigraphic unit between the Elsterian and the Saalian *sensu strictu* (Urban, 1995a) and further interstadials and stadials. The sediment sequence of this 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). These lacustrine sediments of Cycle II have been found to occur at archaeological sites Schöningen 12 and 13 (Thieme *et al.*, 1993; Thieme and Mania, 1993; Thieme, 1996, 1997, 1999; Urban, 1999), marking the extension of the basin (channel), which had a width of at least 1000 m.

Recent investigations give evidence for at least 13 local pollen assemblage zones (LPAZ). Eleven of them are presented in

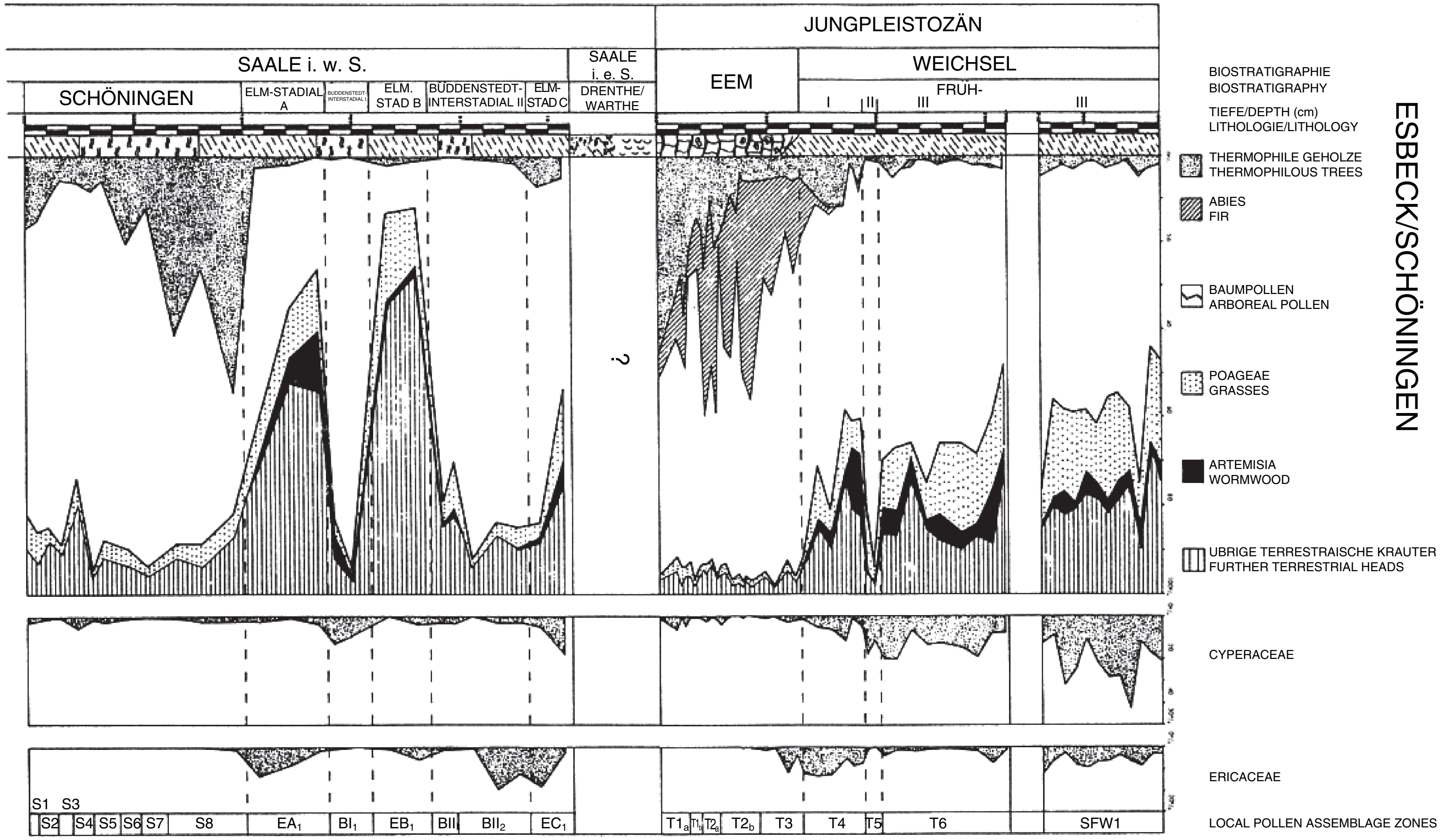

Fig. 28.6 Schöningen and Eemian pollen sum curves.

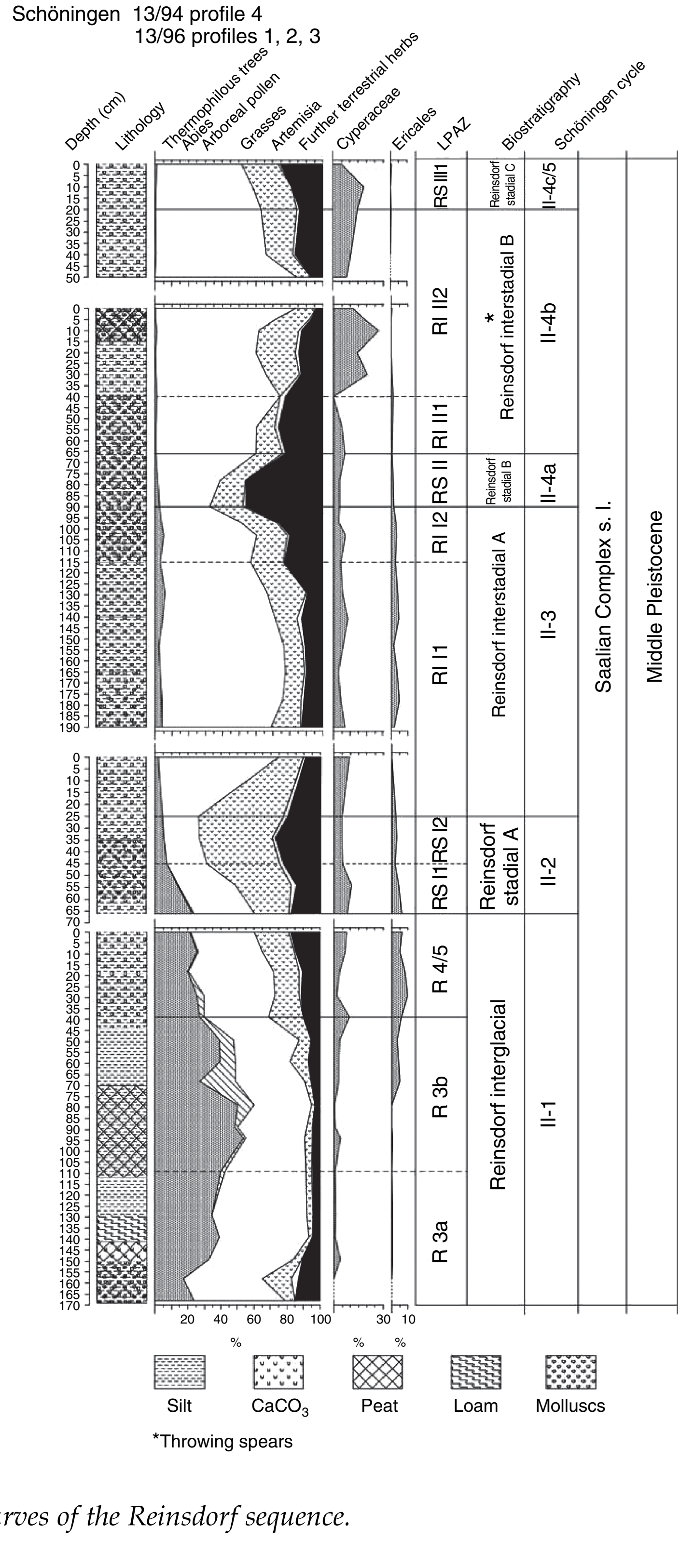

Fig. 28.7 Pollen sum curves of the Reinsdorf sequence.

this article on new pollen diagrams (Fig. 28.7, Figs. 28.9–28.12) that show a fivefold division of the middle and upper part of the interglacial and a sequence of five climatic oscillations subdivided into eight LPAZ following the interglacial (Table 28.1). From the relative high values for grasses and herbs in the inferred forested

Table 28.1 Pollen zones of the Reinsdorf sequence (Cycle II, levels 1–5)

Local pollen assemblage zones (LPAZ)	Characteristic floral elements	Biostratigraphy	Schöningen cycle
?	?	?	II- 5
RS III 1	*Herbs–Poaceae–Betula*	Reinsdorf Stadial C	II- 4c/II-5
RI II2	*Pinus*– (*Picea–Betula, cf. Larix*)	Reinsdorf Interstadial B * throwing spears made from spruce	II- 4b
RI II1	*Betula–Herbs* (*cf. Larix*)		
RS II	*Juniperus–Poaceae–Herbs* (*cf. Larix*)	Reinsdorf Stadial B	II- 4a
RI I2	*Pinus–Poaceae–Herbs* (*cf. Larix*)	Reinsdorf Interstadial A	II- 3
RI I1	*Pinus–(Piceae–Alnus)–Herbs*		
RS I 2	*Poaceae–Herbs Cyperaceae–*	Reinsdorf Stadial A	II-2
RS I 1	*Salix–Calluna*		
R 4/5	*Pinus–Ericaceae*		II-1
R 4	*Carpinus–Picea–Abies*	Reinsdorf Interglacial	
R3/R2	*Corylus–Alnus*		
R1	*Quercus–Fraxinus–Tilia*		
Early phases are lacking			

periods of the interglacial, a warm dry forest steppe climate can be deduced.

Level II-1 represents the maximum temperature and terminal phases of the Reinsdorf Interglacial (Fig. 28.8). The vegetation succession, described by LPAZ (see as well Urban, 1995a), is as follows: a *Quercetum mixtum* phase, LPAZ R3a, followed by a *Corylus–Alnus* phase, LPAZ R3a/b, a *Carpinus–Picea–Abies* phase, LPAZ R3b, and a *Pinus*–Ericaceae zone, LPAZ R4/5 (Figs. 28.9, 28.10). The water fern *Azolla filiculoides* occurs frequently during the *Quercetum mixtum* phase. The interglacial ends with an opening of the pine-birch forest and a strong increase of grasses, terrestrial herbs and Ericales (Reinsdorf Stadial A: LPAZ RS I1 and RS I2, Figs. 28.9, 28.10).

Lake shore sediments of the Reinsdorf interglacial level II-1 (Figs. 28.9, 28.10) contain abundant wood (Schoch, 1999), plant macrofossils (Jechorek, 2000), bones of

Fig. 28.8 Exposure of Cycle II limnic telmatic sediments overlying sand and gravel, sequence II-1: Reinsdorf Interglacial. 2004.

large mammals such as rhinoceros (*Stephanorhinus kirchbergensis*), straight tusk elephant (*Palaeoloxodon antiquus*), bear (*Ursus spec.*), horse (*Equus mosbachensis*), red deer (*Cervus elaphus*), deer (Capreolus capreolus) and the bovide *Bos primigenius* (Thieme *et al.*, 1993; van Kolfschoten, 1995). Fossil remains of small and large rodents are also quite common in level II-1 as are remains of molluscs (Mania and Mai, 2001), birds, fish, reptiles (Böhme, 2000), beetles and other insects. Numerous flint artifacts, wooden tools made of fir, and bones with cut marks found in level II-1 (Thieme, 1996, 1997, 1999) indicate early human occupation of the site during Lower Palaeolithic times. Level II-1 is characterised by *Acer campestre, Acer tataricum, Tilia cordata, Fraxinus excelsior, Prunus spinosa, Cornus sanguinea* and *Crategus monogyna*, elements of slightly open deciduous forest, and by *Abies alba*, *Taxus baccata*, *Carpinus betulus*, *Sorbus torminalis*, *Berberis vulgaris*, *Sambucus nigra*, *Cerasus avium*, *Lonicera xylosteum*, elements of mesophilous mixed deciduous forests as demonstrated by karpological findings (Jechorek, 2000).

The occurrence of the Pannonian floral element, *Linum austriacum* (Jechorek, 2000), points to 1.5–2 °C higher annual temperatures compared to the present. The occurence of *Zannichellia palustris* indicates the presence of saline water, while occurrences of *Potentilla anserina, Rumex maritimus* and *Chenopodium rubrum* may point to slightly saline soil conditions. The presence of saline conditions is supported by chemical analysis of the sediments (Urban, unpublished data).

Sediments of level II-2 are calcareous muds, which, in combination with a marked increase of grasses and a predominance of herbs and shrubs, denotes cool climatic conditions of Reinsdorf Stadial A (Figs. 28.9, 28.10; Table 28.1).

Level II-3 sediments are organic mud and peat representing an interstadial period, named locally Reinsdorf Interstadial A (Figs. 28.10, 28.11). The vegetation was dominated by *Pinus,* with *Betula, Alnus*, and a few *Picea* (LPAZ RI I1 and RI I2). Trees indicative of a warm climate are almost absent.

Level II-4 (Figs. 28.11–28.13) contains two stadials separated by an interstadial (Reinsdorf Stadials B and C and Reinsdorf Interstadial B), which comprise a transition into level II-5. Sediments are calcareous mud, organic mud and peat. The onset of climatic deterioration in the lower part of level II-4 is reflected by a dominance of herbs indicating a steppe environment (level II-4a, Reinsdorf Stadial B: LPAZ RS II). The upper part of level II-4 is characterised by a *Pinus* forest, with *Betula* (level II-4b, Reinsdorf Interstadial B, LPAZ: RI II1 *Betula*–*Pinus* zone and RI II2 *Pinus*–*Betula*

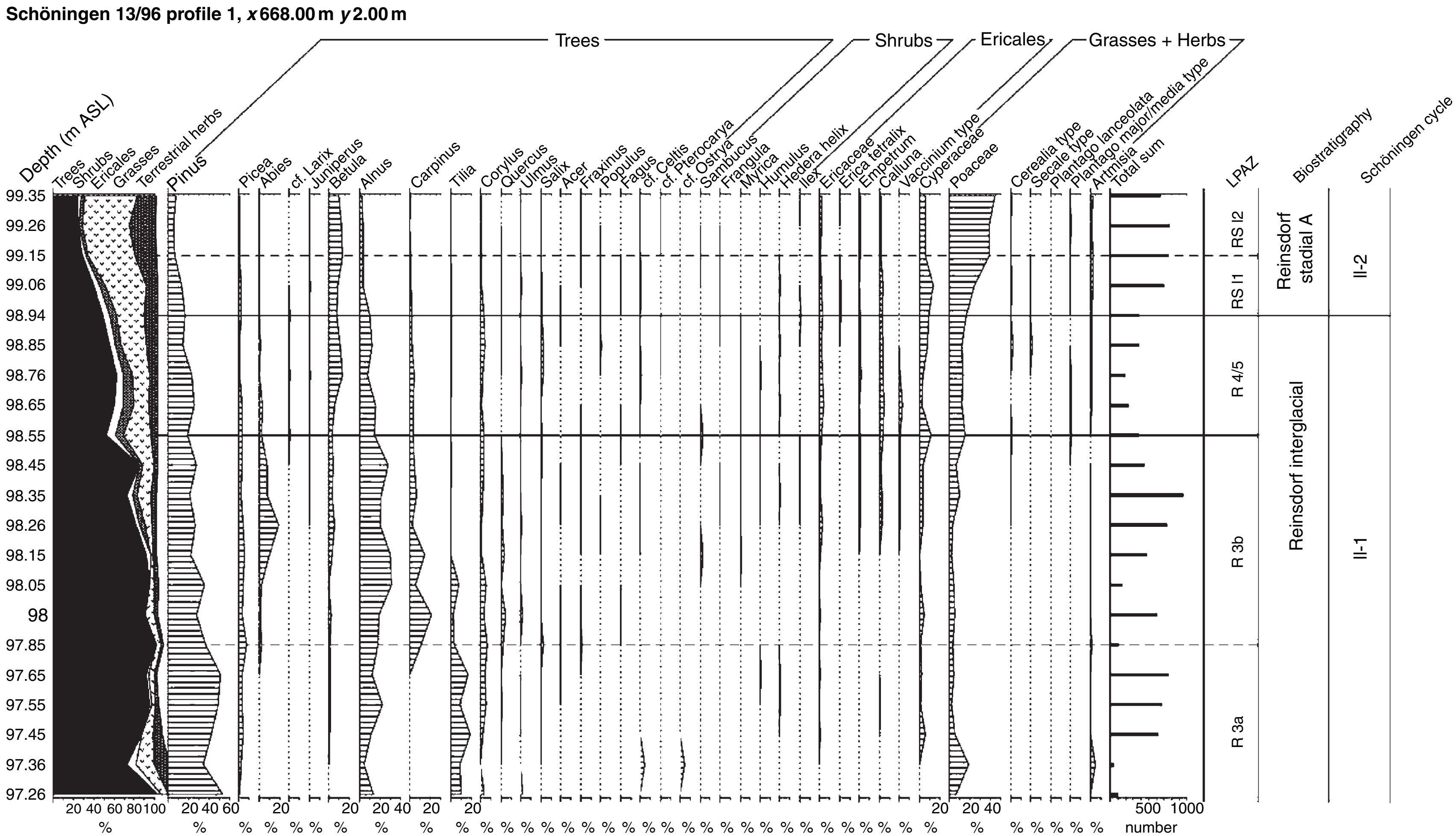

Fig. 28.9 Cycle II-1, II-2 (Reinsdorf Interglacial, Reinsdorf Stadial A, profile 1, Schöningen 13/96).

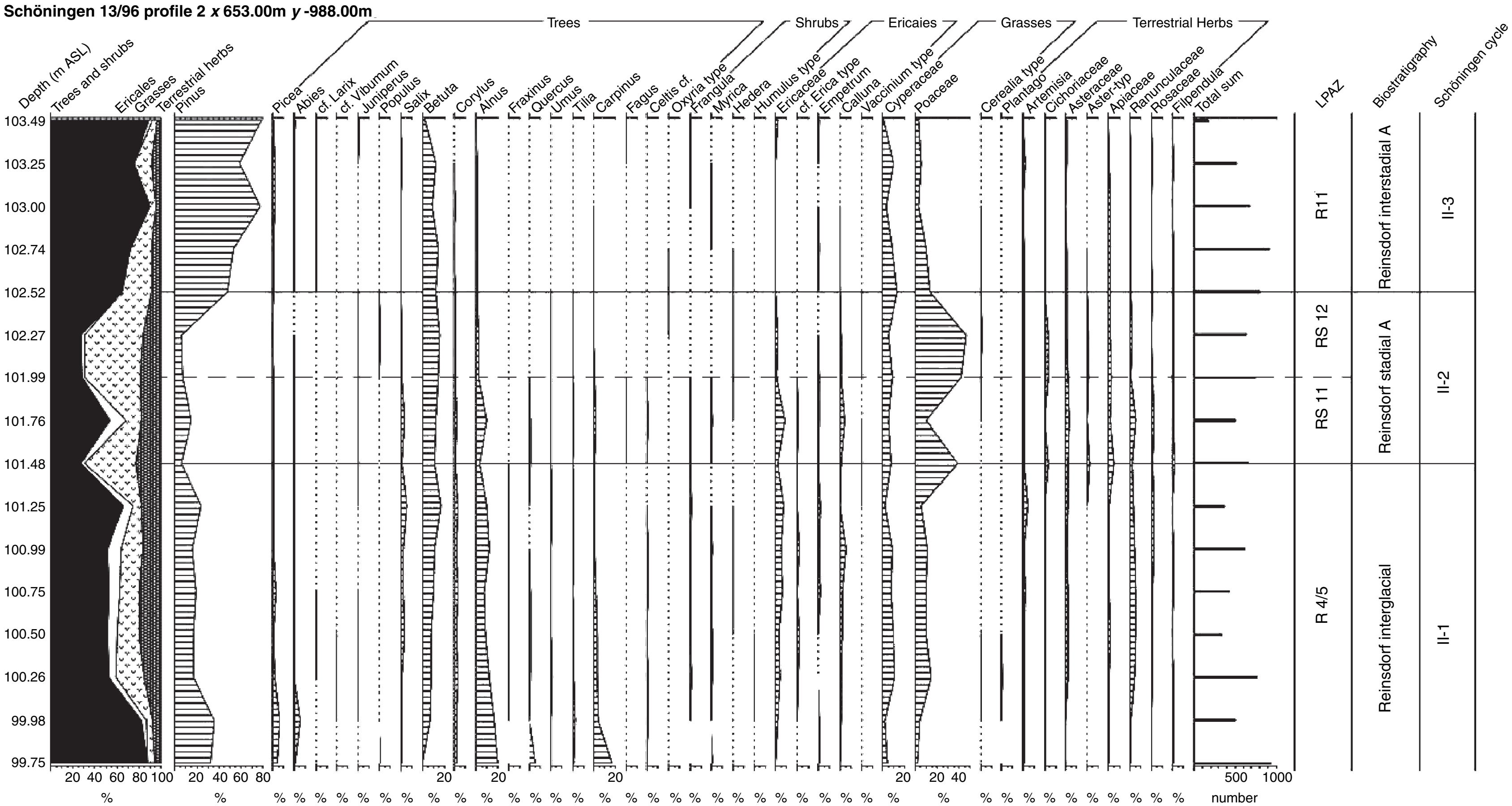

Fig. 28.10 Cycles II-1, II-2, II-3 (Reinsdorf Interglacial, Reindorf Stadial A, Reinsdorf Interstadial A, profile 2, Schöningen 13/96).

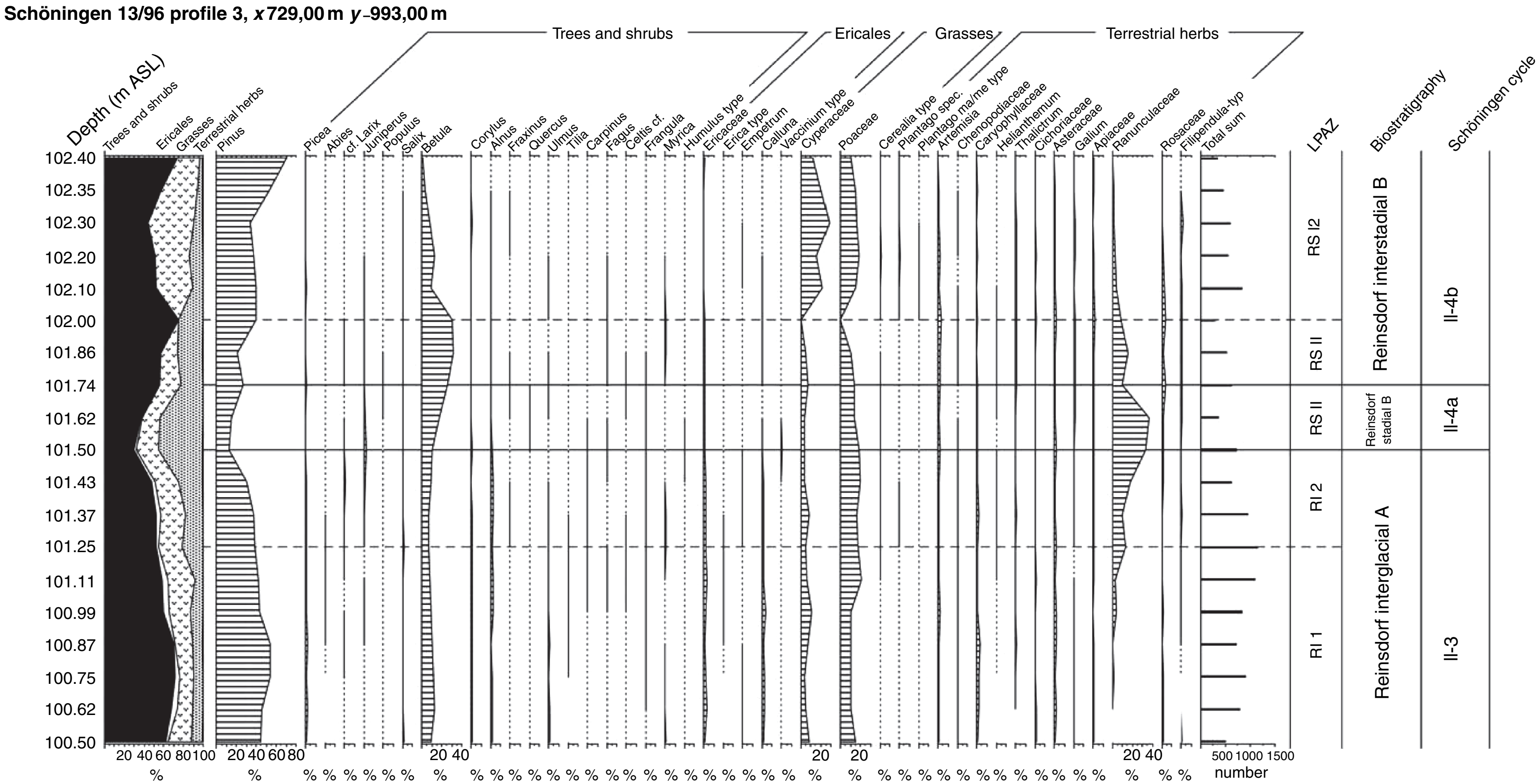

Fig. 28.11 Cycles II-3, II-4a, II-4b (Reinsdorf Interstadial A, Reinsdorf Stadial B, Reinsdorf Interstadial B, profile 3, Schöningen 13/96).

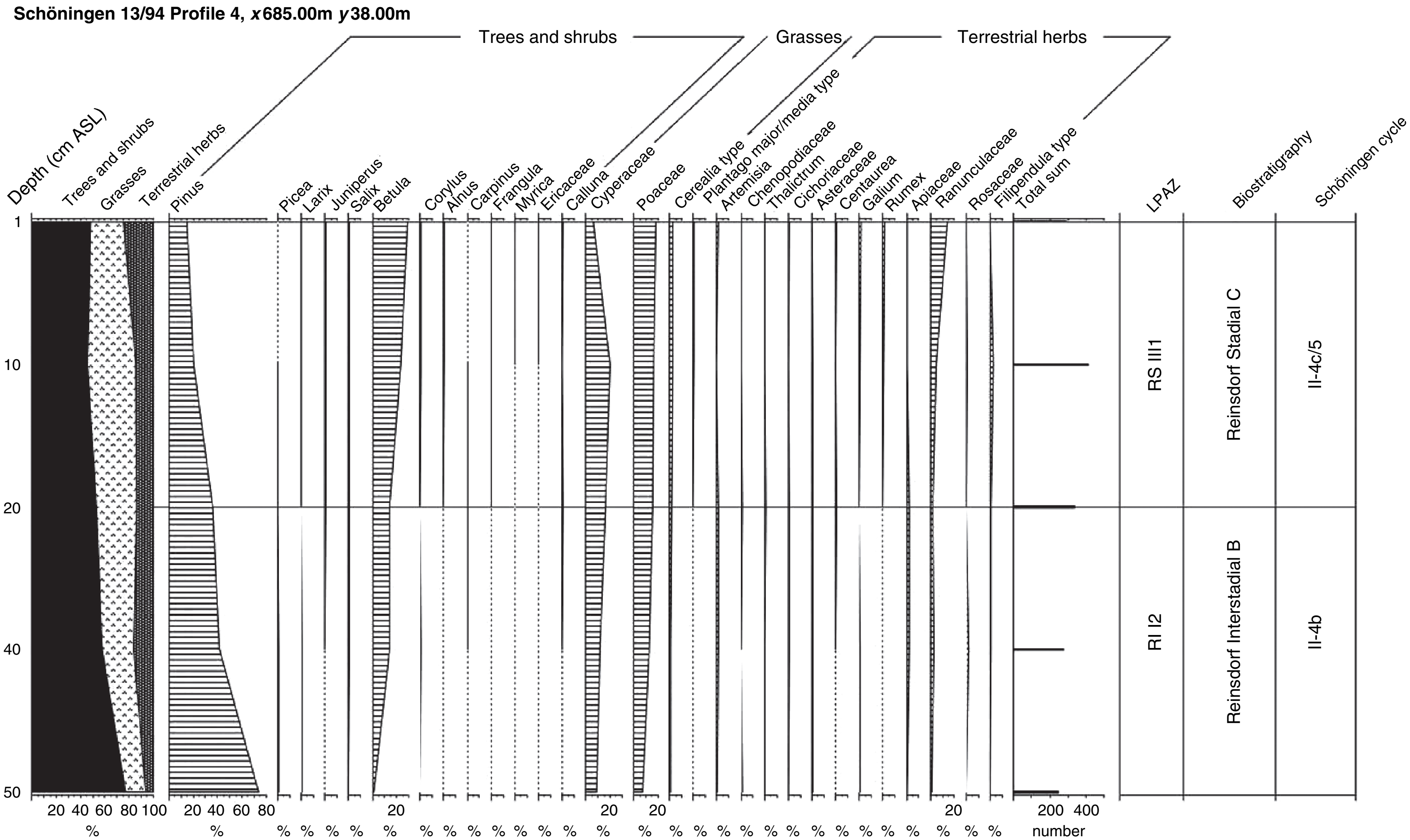

Fig. 28.12 Cycles II-4b, II-4c/II-5 (Reinsdorf Interstadial B, Reinsdorf Stadial C, profile 4, Schöningen 13/94).

Fig. 28.13 Cycle II, sequence II-4b: Reinsdorf interstadial B (strata of throwing spears) and sequence II-4c/II-5: Reinsdorf stadial C (cryoturbation of top sediments) 2004.

zone) (Figs. 28.12, 28.14). Pollen of *Picea* is very rarely found in Reinsdorf Interstadial B deposits.

Jechorek (2000) identified macrofossils of *Arctostaphylus uva-ursi, Carex aquatilis, Frangula alnus, Pinus sylvestris, Lonicera xylosteum, Rubus ideaus* and *Salix spec*. in level II-4 sediments.

Level II-4b also yielded numerous faunal remains, mainly horse, flint artifacts and well-preserved spears made from spruce, the oldest hunting spears so far discovered (Thieme, 1999). The pollen assemblage of level II-4b (Figs. 28.11, 28.12) contains only very rare *Picea* pollen, which might suggest transportation of the hunting weapons from scattered stands of spruce some distance from the site.

Between level II-4c (Reinsdorf Stadial C, LPAZ: RS III1, nonArboreal zone) and II-5, within silty clays, frost structures occur and mark the onset of a periglacial environment and the definite end of cycle II (Fig. 28.13).

In summary, the karpological investigations of the Reinsdorf sequence (Jechorek, 2000) reveal remains of 132 plant species including seven thermophilous exotics: *Acer tartaricum, Acorellus pannonicus, Thymelaea passerina, Viola cf. alba, Ranunculus brutius, Ranunculus lateriflorus A. Dc. vl. nodiflorus L., Dychostylis micheliana* and *Potamogeton vaginatus*. In agreement with the palynological findings, a warm climatic forest steppe type of vegetation indicating rather dry regional conditions can be inferred for the main part of the Reinsdorf Interglacial. Preliminary ^{230}Th/^{234}U age determinations of peat layers within the Reinsdorf interglacial deposits (level II-1) at site Schöningen 12 (Heijnis and Urban, 1995) gave an approximate age of 320 kyr.

28.2.4 Schöningen (Cycle III)

Channel III contains a sedimentary sequence (Cycle III) that cross-cuts Channel II (Figs. 28.2, 28.6). The sequence is composed of silty muds and peats and represents the Schöningen interglacial (Urban *et al.*, 1991b; Urban, 1992, 1995a). The pollen assemblages are indicative of a warm, (sub)continental climate with high percentages of *Pinus* and *Tilia* with some *Quercus*. High components of *Alnus* found almost throughout the entire profile point to swampy environments. A *Carpinus* phase with *Picea* occurs near the end of the warm period. *Abies* is absent, apart from a single grain, while 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 characterised by a marked increase of herbs and moderate increases of *Artemisia*, grasses and Ericales (Fig. 28.6). The Elm A Stadial is followed by two temperate periods, the Büddenstedt I and II Interstadials, with pollen assemblages indicative of *Pinus*–*Betula* forests. The Büddenstedt interstadials are separated by the Elm B Stadial. Increases of *Betula* and herbs mark the onset of another cold spell, the Elm C Stadial which caps the sequence (Fig. 28.9). The interglacial and stadial–interstadial sequence of Channel III (Cycle III) is overlain by glaciofluvial sands and till

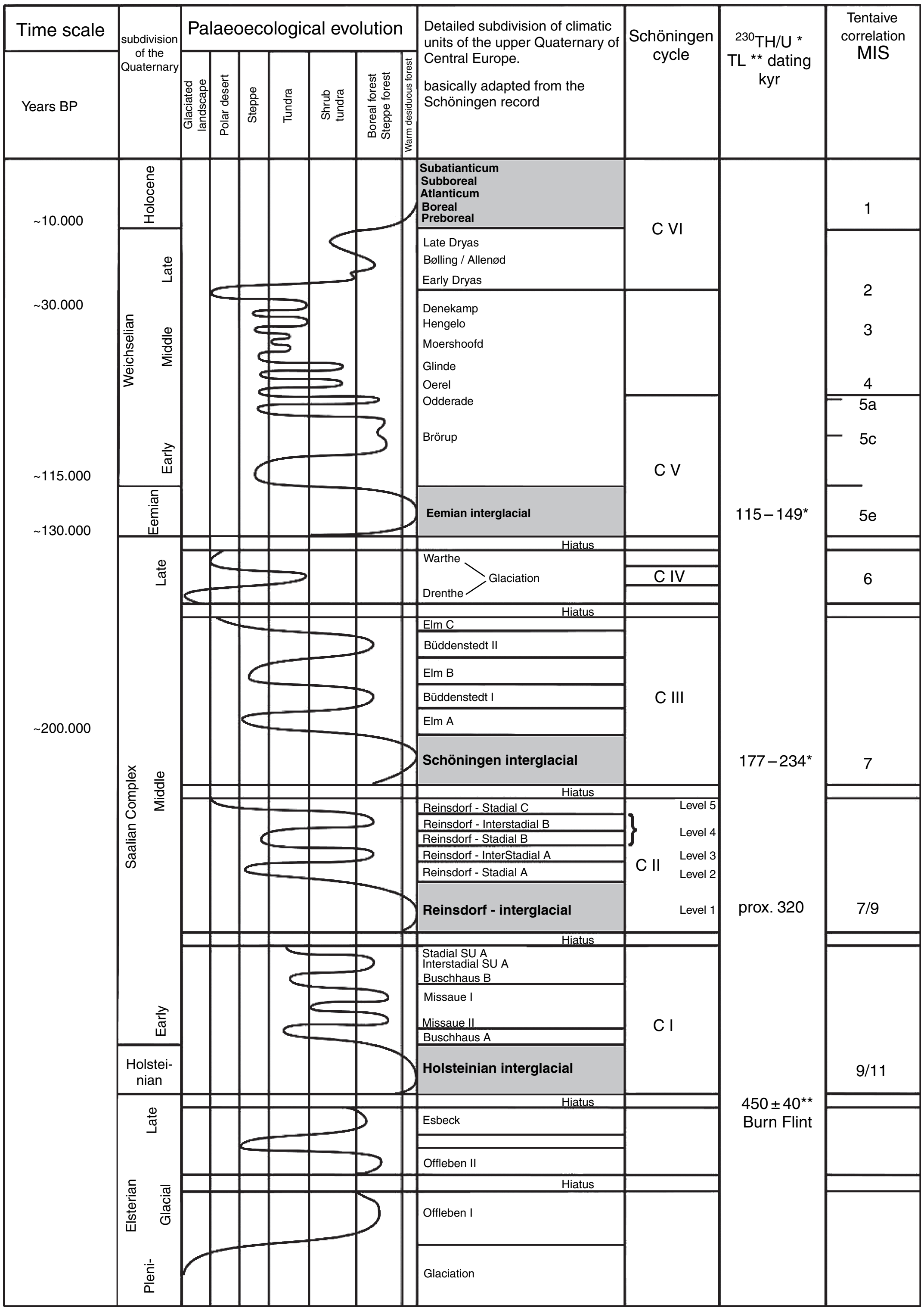

Fig. 28.14 Synthesis of the Schöningen pollen records, dating and tentative correlation with the marine isotope stages.

of the first Saalian ice advance (Drenthe Stadium). Peat of the Schöningen interglacial gave uncorrected $^{230}Th/^{234}U$ ages of 180 and 227 kyr (Heijnis, 1992). Based on the pollen record, correlation has been made with the Wacken (Menke, 1980) and Dömnitz (Erd, 1973) interglacials (Urban *et al.*, 1991b; Urban, 1995a).

28.2.5 Cycle IV

Channel IV, which is eroded into Saalian glacial deposits, contains a pedocomplex developed in alluvial loess. Two pseudogleyic layers, presently being analysed by Altermann (personal communication) suggest the presence of at least one periglacial phase between the two major ice advances of the Saalian glaciation (Drenthe and Warthe Stadium, Figs. 28.2, 28.14), which is recorded with tundra-type vegetation and soils from the Red Cliff on the Isle of Sylt (North Western Germany) (Felix-Henningsen and Urban, 1982)

28.2.6 Eemian (Cycle V)

The sequence in Channel V (Cycle V) is represented by either a Luvisol developed in loess, or, due to the influence of the palaeodrainage system, a soft travertine and peat of last interglacial age. In Schöningen, interglacial sedimentation started concurrently with a *Carpinus* phase and continued to the first Early Weichselian interstadial (Figs. 28.5, 28.6). The Eemian peat and travertine layers are rich in *Abies* during the *Pinus-Picea-Abies*-Zone. The travertine sediments were deposited during a period of about 6000 years, deduced from the reconstructed pollen zones (Müller, 1974a). Local hydrological conditions during the late last interglacial and early glacial periods have been determined by pollen analysis and by plant macro remains, specifically moss analyses (Hölzer in Urban *et al.*, 1991a). The Eemian peaty layers reveal a thorium/uranium age of 132 ± 17 (Heijnis, 1992) (Table 28.2, Fig. 28.14).

28.2.7 Holocene (Cycle VI)

The youngest sedimentation cycle in the Schöningen mine is comprised of Late Weichselian and Holocene deposits and soils (Channel VI sediments), and braided river deposits of the Mißaue and its tributaries. The variety of both sediments and soils has allowed a detailed reconstruction of the vegetation history, palaeo landscape and the degree of human impact on the area (Figs. 28.2, 28.5) (Thieme *et al.*, 1987; Thieme and Maier, 1995).

28.3 DISCUSSION

The sequence of Schöningen gives geological and palaeoecological evidence for several temperate phases between the Holsteinian and the Eemian and reveals data on three interglacials and at least 10 interstadials between the end of the Elsterian and the beginning of the Saalian (Drenthian) glaciation (s.str.).

Some authors state that, as (temperate) deposits investigated in Schöningen do not occur in the same outcrop in perfect superposition, the succession of the warm stages will remain to some extent debatable (e.g. Turner, 1998). In contrast, we believe, from intensive geological field work, mapping and analysis of long geological transects since the opening of mine Esbeck in the 1980s, the superposition of stratigraphic units, the overlapping of sedimentation units which cut or underlay the strata at certain times of excavation and adjacent occurrences of channel fillings, that a stratigraphic sequence has been well established (Elsner, 1987; 2003; Hartmann, 1988; Urban *et al.*, 1988, 1991a, 1991b; Lenhart, 1989; Tschee, 1991; Thieme *et al.*, 1993; Mania, 1995, 1998). Moreover, palaeoecological and biostratigraphic evidence, archaeological findings and radiometric dating have resulted in a comprehensive stratigraphic scheme for the glaciated margin of Western Central Europe.

28.3.1 Late Elsterian, Offleben I and II and Esbeck Interstadials

The Offleben I, II and the Esbeck interstadials, which are related to late phases of the Elsterian glaciation, but not to its late glacial period, occurring on top of the youngest Elsterian till, have no known biostratigraphic equivalent

Table 28.2 Tentative correlation of the Schöningen sequence with the Velay record (Reille and de Beaulieu, 1995; Reille *et al.*, 1998; de Beaulieu *et al.*, 2001)

Germany NE Niedersachsen Urban *et al.*, 1988, 1991a, 1991b; Heijnis, 1992; Urban, 1995a, 1999, 2000; Urban and Heijnis, 1995		**South Central France** Reille and de Beaullieu, 1995; Reille *et al.*, 1998; de Beaullieu *et al.*, 2001	**MIS**
Eemian	^{230}Th/^{234}U 132 +/- 17 kyr	**Ribains**	5e
Elm C			
Büddenstedt II		Le Bouchet 3	
Elm B		Belvezet	
Büddenstedt I		Le Bouchet 2	
Elm A Stadial		Bonnefond	
Schöningen	^{230}Th/^{234}U 180 and 227 kyr	Le Bouchet 1	7 ?
?		?	
Harbke interstadial		?	
Reinsdorf Stadial C	(II-4/5)	Charbonniers Stade	
Reinsdorf Interstadial B	(II-4)	Amergiers Interstade	^{40}Ar/^{39}Ar 275 +/- 5kyr
Reinsdorf Stadial B	(II-4)	Monteil Stade	
Reinsdorf Interstadial A	(II-3)	Ussel Interstade	
Reinsdorf Stadial A	(II-2)	Cayres Stade	
Reinsdorf	^{230}Th/^{234}U prox. 320 kyr?	**Landos**	7/9 ?
Stadial SU A		Bargette Stade	
Interstadial SU A		Jagonas Interstade 2	
Buschhaus B Stadial		Pradelle 2	
Missaue Interstadial (Missaue I, II)		Jagonas Interstade 1	
Buschhaus A Stadial			
Holsteinian		**Praclaux**	9/11 ?

elsewhere in Northern Germany and Western Europe. Attention should be paid to their relevance for correlation with the marine isotope record as they are preceding the classical Holsteinian interglacial and might be of significance for Late Elsterian climatic evolution.

28.3.2 Holsteinian, Missaue I and II Interstadials, Buschhaus B Stadial and Interstadial SU A

In Schöningen late phases of the Holsteinian interglacial and two following interstadials are documented (Urban *et al.*, 1991a, 1991b; Urban, 1996a, 1996b). The terminal phases of the Holsteinian, which contain *Abies*, *Pinus*, *Picea*, *Pterocarya* and water fern *Azolla filiculoides*, have been correlated with pollen zones XII, XIII and XIV (Müller, 1974b; Meyer, 1974). A strong cooling at the end of the Holsteinian marks the onset of the Saalian s.l.. This event, the Buschhaus A Stadial of the Schöningen sequence, can be correlated with the Fuhne A Stadial at Pritzwalk/Prignitz (Erd, 1973). The twofold Mißaue interstadials I and II are equivalent to the Dockenhuden interstadial (Hallik and Linke, 1986; Urban, 1996a) and to the Pritzwalk interstadial A/B (Erd, 1973; Erd *et al.*, 1987). In comparison with investigations at Bossel (northwest Niedersachsen), a site with sediments of the Holsteinian marine transgression (Müller and Höfle, 1994), the early part of the twofold Mißaue interstadial may be correlated with zone XVI/XVII.

Looking at the occurence, distribution and succession of certain taxa (*Carpinus/Fagus, Pterocarya, Abies* and *Azolla filiculoides*) in late Holsteinian sequences, not only of areas adjacent to the North Sea Basin (Zagwijn, 1973) but also of lower European latitudes, including the long sequence of the Velay (de Beaulieu *et al.*, 2001) and La Cote in Vercors, France (Field *et al.*, 2000), the sites of Samerberg II in Bavaria (Grüger, 1983), Thalgut in Switzerland (Welten, 1988) and Krepiec, Zbojno and Losy in Poland (Lindner and Marciniak, 1998) are of significance. Long-distance correlation of the Praclaux interglacial with the Holsteinian has been proposed by de Beaulieu *et al.* (2001), and of the Mazovian by Lindner and Marciniak (1998), suggesting it a probable terrestrial correlative of stage MIS 11. Referring to Sarnthein *et al.* (1986), who ^{230}Th/^{234}U and ESR dated marine molluscan shells from para-type and other Holsteinian interglacial deposits to >350 and 370 kyr, Holsteinian beds have been correlated with MIS 11 or even an older interglacial event.

There is ongoing debate on the exact age of the Holsteinian interglacial. Geyh and Müller (2005) recently presented ^{230}Th/^{234}U dates and a palynological review of the Holsteinian/Hoxnian interglacial. Their interpretation of ^{230}Th/^{234}U dates has led them to correlate the Holsteinian and the Hoxnian (Turner, 1970) with MIS 9. The authors present a brief review of correlations of the Holsteinian with MIS 11 citing mainly palynological work. Among those, their citation that, by using ^{230}Th/^{234}U dates of peat of the Schöningen interglacial (Figs. 28.10, 28.12), Urban (1983, 1995a) 'palynologically and indirectly correlates the Holsteinian interglacial to MIS 11' is causing confusion and has to be corrected. As cited above, peat of the Schöningen interglacial revealed uncorrected ^{230}Th/^{234}U ages of 180 and 227 kyr (Heijnis, 1992) and therefore can be related most appropriately to MIS 7 (Urban, 1995a). It can, therefore, not be used as an indirect correlation tool for dating the Holsteinian to MIS 11 (Fig. 28.14).

There is further evidence that the Kärlich interglacial sequence (Urban, 1983; Bittmann, 1992) might reveal two different interglacials (Urban, manuscript in preparation). Urban (1983), based on the palaeofloristic record, tentatively proposed a post-Holsteinian age for the Kärlich interglacial s.str. Bittmann has correlated the Kärlich interglacial sequence palynologically to the Bilshausen interglacial (Müller, 1965; Bittmann and Müller, 1996) and an ^{40}Ar/^{39}Ar age of about 400 kyr obtained from a tephra layer predating the Kärlich interglacial (van den Boogaard *et al.*, 1989: $396 + -20$ kyr) to the Cromerian (V). Refering to recent dating, van den Boogard (in Boenigk and Frechen, 1998) relates the eruption of the 'Kärlicher Brockentuff' to the beginning of MIS 10. Boenigk and Frechen (1998) place the Kärlich interglacial s.str. (Urban, 1983), by correlation with sequences from the Lower Rhine area, into the Saalian s.l., a correlation which had already been suggested by Urban (1983).

The Holsteinian deposits of Schöningen have not been dated so far. There is a TL date of a burnt silex from a prehistoric fire place (Richter, 1998) in Late Elsterian/Early Holsteinian deposits (Urban, unpublished data) available for the Schöningen mine, revealing an age of 450 ± 40 kyr (Fig. 28.14). The pollen record of those deposits point to an open tundra-(taiga) environment with pine and birch and indicate late glacial Elsterian environmental conditions.

As there is dating and palaeoecological evidence of interglacial sequences following the Holsteinian, attention will be focussed on these superimposed strata of mine Schöningen and their biostratigraphic correlation and preliminary dating.

28.3.3 Reinsdorf Interglacial, Reinsdorf Stadial A, Reinsdorf Interstadial A, Reinsdorf Stadial B, Reinsdorf Interstadial B, Reinsdorf Stadial C, Harbke Interstadial and Schöningen Interglacial

The term Reinsdorf Interglacial was introduced by Urban (1995a) for a new interglacial sequence at Schöningen of post-Holsteinian and pre-Drenthe age (first

Saalian ice advance), which yielded abundant fossil remains as well as archaeological evidence for the presence and activities of *Homo erectus* (Thieme and Maier, 1995). The archaeological site is still exposed, and the excavation and research continues under the supervision of Hartmut Thieme (Archaeological Survey of Lower Saxony, Hanover).

As stated earlier, the Reinsdorf sequence contains interglacial and stadial–interstadial floras (Table 28.1) that are quite distinct from the Holsteinian (Urban, 1995a, 1995b, 1999). The main characteristics of the Reinsdorf Interglacial are a climatic optimum characterised by a forest phase with the spread of *Tilia* before *Corylus; which is only represented by low values, and by the occurrence of a late and less pronounced Abies* phase. Furthermore, the Reinsdorf sequence is characterised by two pronounced interstadials interrupted by phases of climatic deterioration (stadials), when the vegetation opened up to grass and herb-rich steppic environments (Table 28.1, Figs. 28.9–28.12, 28.14). Compared to the Holsteinian vegetation reconstructed from the same outcrop, a warm and distinctive continental regional type of climate can be inferred for the Reinsdorf Interglacial, indicated, for example, by occurrences of *Acer tartaricum* and *Larix,* as well as by low representation of *Corylus*. *Larix* also occurs during the interstadial and stadial phases. These climatic interpretations are supported by the mollusc assemblages (Mania and Mai, 2001).

A 16-m profile covering the biostratigraphic units of the Reinsdorf sequence at the excavation site is presently under investigation. Thermal ionization mass spectrometry (TIMS) ^{230}Th/U dating of peat taken from this profile is currently in progress (Frechen *et al.*, this volume).

The Schöningen interglacial fen peat deposits (Fig. 28.6) contain a distinctive vegetational succession, dominated by *Pinus* and *Alnus* throughout the entire thermal part of the sequence. The Schöningen Interglacial terminates abruptly and is succeeded by a taiga-tundra type of vegetation and then two short boreal conifer phases. Urban (1995a) already discussed the main differences between the pollen zones, marker species and local as well as regional environments in the Holsteinian, Reinsdorf and Schöningen and the probable correlatives of the latter, the Wacken (Menke, 1980), Dömnitz (Erd, 1973) as well as the Eemian interglacial floras in the Schöningen mine in great detail. It was concluded that the Reinsdorf and Schöningen interglacials differ strongly from each other in the following features which have proven to be of biostratigraphic value for long-distance correlation:

1. Absence of *Abies* **(Schöningen)**,
2. Occurence of an *Abies* phase during the *Carpinus–Picea* phase **(Reinsdorf)**
3. *Tilia* peaks during the *Corylus* and early *Carpinus* phases **(Schöningen)**
4. Expansion of *Corylus* with low values and only after that of the Mixed-oak forest phase (*Quercetum mixtum*, QM), dominated by *Tilia* **(Reinsdorf)**
5. **Reinsdorf** interglacial characterised by a warm, continental regional forest steppe climate
6. Dominance by *Alnus* and *Pinus* in all observed pollen zones **(Schöningen)**.
7. An abundance of *Pinus* but only local importance of *Alnus* reflecting the moist hydrological conditions of the stands **(Reinsdorf)**

There are only few sites with records of similar age or of similar biostratigraphic significance to Schöningen from neighbouring areas. However, the Holsteinian and post-Holsteinian deposits from Morsleben and Ummendorf (Aller Valley, Saxony-Anhalt) described by Strahl (1999), which are located less than 10–15 km distance of the Schöningen mine with comparable geological, geogenetical origins, are of special interest as they might contain equivalents of the Reinsdorf Interglacial. Strahl (1999) has considered the Aller interglacial, which follows the Holsteinian, the deposits of which are overlain by the Morsleben Stadial A, Morsleben Interstadial B and Morsleben Stadial C, a most probable time correlative of the Reinsdorf, Wacken (Menke, 1968) and Dömnitz in the profile of Pritzwalk/ Prignitz (Erd, 1973). As stated earlier, the Holsteinian at Schöningen is followed by the Buschhaus A stadial, which is considered to mark the onset of the Saalian Complex s. l. This is followed by a twofold temperate phase, the Missaue I and II Interstadials and the Buschhaus B Stadial characterised by a steppe environment which was followed by another temperate phase, Interstadial SU A (Figs. 28.3, 28.14). Though in Morsleben only one interstadial (Morsleben Interstadial B) is recorded, which might point to some discordances/hiatus between the post Holsteinian interstadials and the deposits of the Aller interglacial in that section, it has certain similarities with the Reinsdorf interglacial. Strahl (1999) records four pollen zones of the Aller interglacial, including a *Carpinus*–*Abies*–*Picea*–*Alnus* zone, which have correlatives in the Reinsdorf interglacial pollen zones (R3–R5).

Unfortunately, only descriptions of pollen zones without diagrams have been published by Strahl so far, prohibiting more detailed comparison. The correlation of the Aller interglacial and the Wacken and Dömnitz interglacials still remains rather tentative as they differ palaeobotanically strongly from the Aller and Reinsdorf interglacials. There is no evidence from the Morsleben site of two interglacials following the Holsteinian and preceding the first Saalian ice advance.

However, two interglacials are recorded by Müller (personal communication, 1999 and 2005) from pit Nachtigall (Niedersachsen). Müller found evidence of a first interglacial, which is rich in *Tilia* and characterised by a late *Abies* phase immediately following the Holsteinian and the early Saalian interstadials described in Schöningen (Urban, 1999), and of a subsequent interglacial, which is lacking *Abies* and which is dominated by *Alnus* and *Pinus*. In summary, it is most likely that the earliest interglacial of pit Nachtigall is a correlative of the Reinsdorf Interglacial and the second one probably of the Schöningen Interglacial. Another probable botanical equivalent might be found in the cores drilled in Göttingen recorded by Grüger *et al.* (1994). The diagrams b, c and d of Göttingen Ottostraße are reflecting an interglacial sequence, which is interpreted by Grüger *et al.* (1994) as representing three interglacials interrupted by stadials and followed by interstadials. The whole sequence is characterised by several hiatuses and other disturbances, which is reflected by 'noise' in the pollen record. If the diagram zones DA 1–17 (after Grüger *et al.*, 1994) are synthesised, taking into account the hiatuses and some probable sediment contamination including the solifluction layer, the initial phases of one interglacial and at least one following interstadial could be identified as having definite similarities with the Reinsdorf interglacial sequence.

The pollen diagram of the lacustrine deposit of Elsterian to Saalian age (Behre, 2004) at Surheide near Bremerhaven spans the lower and middle parts of an interglacial which is characterized by a pronounced peak of *Corylus*, a late maximum of *Abies* and a lack of *Carpinus*. Behre consequently suggests correlation with pre-Holsteinian rather than Holsteinian or early Saalian sequences of intra-Elsterian age, focussing on the Ferdinandow interglacial (Jancyk-Kopikowa, 1975; Jancyk-Kopikowa and Zarski, 1995). The interglacial deposits of Surheide do not have a correlative in the Schöningen sequence at the present state of investigation.

At Röpersdorf (Erd, 1987), the terminal part of the recorded interglacial is almost lacking. However, based on the pattern of spread and dominance of *Tilia* and *Corylus*, several authors correlated the Ücker interglacial from Röpersdorf with post-Holsteinian and pre-Eemian interglacial deposits. Based on recent results obtained within a drilling project of the Geological Survey of Brandenburg (Landesamt für Bergbau, Geologie und Rohstoffe Brandenburg) in the area of Prenzlau, Hermsdorf and Strahl (2005) point out major disturbances of the lithological setting of the interglacial deposits of Röpersdorf. Similar to Erd (1970), they correlate the interglacial deposits of Röpersdorf with the Eemian interglacial. Mania (1998) correlates the Reinsdorf sequence with Bilzingsleben II, which he considers to date to 400 kyr based on ESR and ^{230}Th/^{234}U determinations. Consequently, he relates it with MIS 11 and the Schöningen Interglacial with Bilzingsleben III, which he correlates with the Dömnitz interglacial (Erd, 1973), citing an ^{230}Th/^{234}U age of 320 kyr for the latter interglacial, which he therefore relates to MIS 9. As there are no comparable longer pollen records available for the travertine sequence of Bilzingsleben, a correlation with the Schöningen sequence in our opinion is rather tentative.

The Reinsdorf interglacial has been correlated by Urban (1995a) with the Zbojnian interglacial in Poland (Lindner and Marciniak, 1998), situated some 500 km east of Schöningen. The Zbojnian interglacial is intercalated between two stadials that follow the Mazovian interglacial which is considered the equivalent of the Holsteinian in Poland. Correlation has been based on the great similarities of the climatic optimum characterised by *Tilia* dominance during the QM zone and the spread of *Tilia* before *Corylus*. Late, terminal phases of the Zbojnian interglacial are characterised by an *Abies* phase with lower values compared to the Mazovian interglacial, which is identical with the *Abies* distribution during the Holsteinian and Reinsdorf observed at Schöningen. De Beaulieu *et al.* (2001) have correlated the Landos interglacial with the Zbojnian, the Reinsdorf and the Ücker (Erd, 1987) Interglacials due to its stratigraphic position below the Bouchet 1 interglacial which is almost lacking *Abies.* Consequently, they correlate Bouchet 1 with the Schöningen, Wacken (Menke, 1968) and Dömnitz (Erd, 1970) interglacials.

It should be noted that long-distance correlation based on vegetation changes and similarities inferred from pollen data and other plant remains between sites with latitudinal, altitudinal and edaphical differences have to take into account dissimilarities in occurrences of taxa or their relative representation (de Beaulieu *et al.*, 2001). Considering these uncertainties, these authors state that marker taxa such as *Pterocarya* are very important. *Fagus* is also important in that it plays a key role in both the Holsteinian and in younger interglacials in the southern part of Central Europe and in contrast to Northern Germany where it appears with very low values during late phases of the Holsteinian, co-occuring with *Pterocarya*.

With reservations and pointing out the tentative character of our correlation with the sequence of Velay (de Beaulieu *et al.*, 2001) and La Côte, Val-de-Lans basin, France (Field *et al.*, 2000), best-estimate comparison of Schöningen with those long terrestrial records for the Middle Pleistocene of Central Europe is presented in Table 28.2. This palynological correlation is supported by the ^{40}Ar/^{39}Ar age of 275 ± 5 kyr of the Armargier interstadial following the Landos interglacial that is tentatively correlated here with the Reinsdorf Interglacial.

A recent reinvestigation of the Meikirch pollen record (Welten, 1982, 1988) in the Swiss Alpine Foreland by Preusser *et al.* (2005) has led to a reinterpretation of its correlation. Whereas Welten (1982, 1988) correlated the youngest of the three interglacial phases with the Eemian and the two older, Holstein 1 and Holstein 2, with the Holsteinian *sensu strictu* and the Dömnitz/Wacken/Hoogeveen (Menke, 1968; Erd, 1970; Zagwijn, 1973) (Fig. 28.1), Preusser *et al.* (2005) favour a correlation of the entire Meikirch complex with MIS 7 mainly based on luminescence dating and comparison with marine climate records. In summary, the pollen record reveals three more or less complete interglacial phases of different climatic character, Meikirch 1, Meikirch 2 and Meikirch 3, which are separated from one another by the Birchli stadial, situated between Meikirch 1 and Meikirch 2, the latter followed by the long period of the Chutzen stadial. The Chutzen stadial is characterised by several colder and milder periods, Chutzen 1 by an open tundra, Grächiswil 1 interstadial by a spread of *Picea* and *Pinus*, Chutzen 2 and Chutzen 3, the coldest phases, interrupted by the Grächwil 2 interstadial which is also characterised by increases of *Picea*, *Pinus* and *Betula*. The Chutzen stadial is followed by the Bütschwil interstadial which is characterised by an open *Betula* forest and remarkable amounts of *Larix.* It is considered to be part of the initial phase of reforestation of the Meikirch 3. Owing to the abrupt change in pollen composition, a hiatus is assumed to occur between the Bütschwil interstadial and the Meikirch 3 interglacial. Concerning the interglacial sequences, Meikirch 2 is described as a temperate interglacial, Meikirch 1 and Meikirch 3 as well-developed warm periods. Preusser *et al.* (2005) state that Meikirch 2 might not be complete, and the climatic gradient between the Swiss alpine foreland and the Massif Central during the interglacials is not known. The sequence shows several similarities as well to the Jagonas interstadials, as well as to the Ussel and the Amargiers interstadial (Reille *et al.*, 2000) (Table 28.2). Owing to the vegetation pattern of Meikirch 1, characterised amongst others by the lack of *Fagus,* a correlation with Holsteinian sequences is most unlikely. Taking all these observations as well as the unknown, perhaps even more pronounced, climatic gradient between the Alpine foreland and western central Germany into account, the Meikirch and the Schöningen pollen records are tentatively compared (Table 28.3). It is not known whether the almost total lack of *Abies* in Meikirch 2 is due to a possible hiatus or whether it reveals the degree of vegetation development. Its temperate character compared to that of the Meikirch 1 and 3 warm interglacials and its similarities with Middle Pleistocene interstadials of the French Central Massif, as stated above, suggests correlation with Reinsdorf Interstadials A and B. With this comparison, Meikirch 1 interglacial might correspond to the Reinsdorf interglacial. Part of the Chutzen stadial sequence might be correlated with Reinsdorf Stadial C and the cryoturbation horizon of the top sediments (Figs. 28.12, 28.13, Table 28.3).

In Schöningen, a peat of 1.5 m thickness topped by limnic sediments contains a pronounced interstadial, named locally the Harbke interstadial (Urban, 1996a). It has been found in a comparable lithostratigraphic position to the peat layer of the Schöningen interglacial in the northern mining field Esbeck, but could not be correlated to date. The Harbke interstadial shows the following characteristics: a *Betula*–*Pinus* zone, followed by a *Pinus*–*Betula*–*Picea* zone and a *Pinus*–NAP zone with increasing amounts of Chenopodiaceae, Polygonaceae, Caryophyllaceae and Asteraceae. During pollen zone Esd V, the *Pinus*–*Betula*–*Alnus*–(Ericaceae–*Sphagnum*) zone, the growth of a local fen peat reached its climax. The *Pinus*–*Betula*–NBP zone marks the end of that biostratigraphic unit. Pollen of *Larix* occurs more or less continuously though with low values throughout the entire profile. If compared with the Meikirch record, the possibly truncated Bütschwil interstadial might comprise part of the Harbke interstadial (Tables 28.2, 28.3).

28.3.4. Eemian (MIS 5e), Early Weichselian (MIS d, c), Late Glacial and Holocene

In Schöningen, the MIS 5e (Bassinot *et al.*, 1994) equivalent travertine sediments were deposited during a period of about 6000 years, deduced from the reconstructed pollen zones (Müller, 1974a) which can be

Table 28.3 Tentative correlation of the Schöningen Middle Pleistocene sequence with the Meikirch record (Preusser *et al.*, 2005)

Germany NE Niedersachsen Urban *et al.* 1988, 1991a, 1991b; Heijnis, 1992; Heijnis and Urban, 1995; Urban, 1995a, 1999, 2002		**Swiss alpine foreland** Preusser *et al.*, 2005	**MIS**
Elm C		-	
Büddenstedt II		-	
Elm B		-	
Büddenstedt I		-	
Elm A stadial		Hubel	
Schöningen $^{230}Th/^{234}U$ 180 and 227 kyr		Meikirch 3	7 ?
?		Hiatus ?	
Harbke interstadial		Bütschwil	
Reinsdorf stadial C	(II-4/5)	Chutzen sequence	
Reinsdorf interstadial B	(II-4)	Mei-	
Reinsdorf stadial B	(II-4)		
Reinsdorf interstadial A	(II-3)	kirch 2	
Reinsdorf stadial A	(II-2)	Birchli	
Reinsdorf $^{230}Th/^{234}U$ prox. 320 kyr?		Meikirch 1	7/9?

correlated with the Eemian and Early Weichselian site of Gröbern (Litt, 1990) and other Northern German Late Pleistocene sequences (Behre, 1974, 1989; Menke and Tynni, 1984; Behre and Lade 1986; Urban in Veil *et al.*, 1992; Hahne *et al.*, 1994; Caspers, 1997). In Schöningen, the terminal part of the interglacial is represented by the *Carpinus*–*Picea* phase indicating rather uniform 'oceanic' climatic conditions and the following *Pinus*–*Picea*–*Abies* phase having a more boreal and suboceanic character in Northwestern and Central Europe (Aalbersberg and Litt, 1999). Hydrological and climatic development of the late last interglacial and early glacial periods have been determined by pollen analyses, plant macro remains and molluscs (Urban *et al.*, 1991a). The Eemian peaty layers reveal a thorium/uranium age of 132 ± 17 kyr (Heijnis, 1992) (Fig. 28.14, Table 28.2). The youngest sedimentation cycle in Schöningen contains late Weichselian and Holocene deposits and soils, which have allowed a detailed reconstruction of Late Glacial and Holocene physical environments and human impact (Figs. 28.5, 28.14) (Thieme *et al.*, 1987, Thieme and Maier, 1995).

28.4. SUMMARY OF STRATIGRAPHIC ASPECTS OF THE SCHÖNINGEN SEQUENCE

In Northwest Europe, Middle Pleistocene post-Holsteinian sequences with a definite stratigraphical position below the Early Saalian till are rather rare. Besides the previously cited correlations based on biostratigraphic findings, several other authors have correlated the Schöningen sequence with long Pleistocene records (e.g. Kukla and Cilek, 1996) and placed the Holsteinian into MIS 11 and the Reinsdorf interglacial into MIS 9.

Jöris and Baales (2003) attempted to correlate the Schöningen sequence with the marine isotope chronology using the Vostok record (Petit *et al.*, 1999) and came to the same conclusion. In their discussion of the stratigraphic position and the age of the throwing spears (Thieme, 1999), which the authors wrongly placed into the Reinsdorf interglacial instead of the following interstadial (Reinsdorf interstadial B of Cycle II-4; Urban, this volume; Thieme, 1999), the authors correlate the Schöningen interglacial with MIS 9a, the early Saalian Drenthe with MIS 8 and the Warthe loess with stage 6.

Both the ^{230}Th/^{234}U ages of 180 and 227 kyr for the Schöningen interglacial and of 132 ± 17 kyr for the Eemian interglacial peat (Heijnis, 1992; Urban, 1995a) suggest a correlation of the Schöningen interglacial with MIS 7 rather than with MIS 9 and the Drenthe till with MIS 6.

Recently, the Antarctic Vostok ice core (EPICA Community Members, 2004; McManus, 2004) provided detailed evidence of climate development over the past 420 000 years. Of particular interest is the ascertainment that the interglacial stage MIS 11, following Termination V, was about 28 000 years long. According to Meyer (1974), Müller (1974b) and Geyh and Müller (2005), the Holsteinian interglacial as determined by counting of annual diatom layers should have covered a period of about 16 000 years. In comparison, the Rhumian interglacial was determined to have been about 25 000 years long (Müller, 1992). Those observations of the particular length of the interglacial periods and botanical pattern are used as an important argument for correlation in addition to thorium/uranium dating of Holsteinian-type locality deposits by Geyh and Müller (2005).

Recent approaches of direct correlation of land–sea records between terrestrial and marine climatic indicators and ice volume proxies from deep-sea core MD01 2447 (off northwestern Iberia) show that the warmest period of MIS 11 lasted about 32 000 years (426–394 kyr) and was followed by three warm/cold cycles (394–362 kyr) (Desprat *et al.*, 2005). During those interstadial/stadial periods, deciduous forests prevailed, and heathland in transition to open grassland characterised the cold steppe-like stadial environments. Of utmost interest in comparison with terrestrial records of early post-Holsteinian age is pollen zone MD47-S2 of the second stadial between 384 and 382 kyr, which is abruptly intercalated between interstadials MD47-I2 and MD47-I3. The same is observed in NW Europe, for example, at Schöningen for the post-Holsteinian twofold Mißaue interstadials I and II, which are equivalent to the Dockenhuden interstadial (Hallik and Linke, 1986; Urban 1996a) and to the Pritzwalk interstadial A/B (Erd, 1973; Erd *et al.*, 1987). They all have a sudden and short cold spell in common, dividing the interstadial into two major parts.

The long warm phase of MIS 11 in northwestern Iberia is named Vigo interglacial. Desprat *et al.* (2005), furthermore, found that the Vigo interglacial of MIS 11 in the marine pollen record off northwestern Iberia shows a floral succession and development similar to that of the Praclaux interglacial (Reille *et al.*, 2000) and with certain features defining the Holsteinian interglacial of Western and Central Europe. Based on those observations, the authors correlate MIS 11 with the Praclaux interglacial and the Holsteinian.

The summary of Fig. 28.14 presents a subdivision of the Quaternary of Western Europe based on the biostratigraphic units of the Schöningen sequence. As the ^{230}Th/^{234}U age determinations on peat, which were the pioneer research of Henk Heijnis (Groningen and Sydney) in the early 1990s, are still preliminary, and as different types of sediments and soils are currently the subjects of dating processes, I propose the scheme (Fig. 28.14) based on biostratigraphic correlatives. As the efforts of determining the exact age of the Holsteinian from the marine sediments of Bossel/Germany (Geyh and Müller, 2005) suggest a correlation with MIS 9, research is now focussing on testing this age determination at different sites and on further age determination of younger interglacial and interstadial peat deposits of definite post-Holsteinian sequences (Frechen *et al.*, this volume). Amongst these, Schöningen is of significance as it contains interglacial and interstadial peat deposits with an undisputable stratigraphical position below early Saalian till.

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