

Palaeobotanical investigations at the mammoth site of Niederweningen (Kanton Zürich), Switzerland

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Abstract

Palaeobotanical investigations at the Niederweningen 2003 mammoth site concentrated on the middle peat layer, in which the remains of mammoth and other vertebrates have been found. This peat developed during an interstadial characterised by the presence of *Picea*. The slopes around the site were occupied by open forest tundra composed of species such as *Picea abies*, *Larix*, and probably *Betula pendula/pubescens*. The herb vegetation was similar to that of modern subalpine grasslands. *Pinus cembra* and *Pinus mugo* were present at higher elevations on the surrounding hills during the time of peat growth. The mire development started with overgrowth processes. During the interstadial the succession developed towards a wetland complex with different mire associations, where among other species *Betula nana* was abundant. The middle peat layer is intercalated with lake sediments, which were deposited during stadial climatic conditions without any noteworthy growth of trees. The pollen spectrum, as well as radiocarbon and luminescence dating, place the peat into the Middle Würmian (Marine Isotope Stage 3). The peat with the mammoth findings is hence significantly younger than the peat layers previously investigated in cores from two nearby drilling sites.

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1. Introduction

Since the end of the 19th century the village of Niederweningen is known as an important site for Quaternary fossil vertebrate bones (Figs. 1 and 2). Beside the remains of at least seven adult mammoths and a mammoth cub, bone remains of wild horse, woolly rhino, steppe wisent, wolf, vole, lemming, and frog have been found in the so-called mammoth hole (Hünemann, 1987). The stratigraphic situation around the mammoth hole is deduced from two cores (KB83-1 and KB83-2) that were palynologically investigated by Welten (1988). This information is supplemented by evidence from a further core (1985) and analysis of an outcrop in the surroundings (Schlüchter, 1988).

After finding an almost complete mammoth skeleton during summer 2003, a series of samples was collected for interdisciplinary investigations. The aim of these investigations is a comprehensive reconstruction of the environmental conditions during the time when the vertebrates

were imbedded as well as a precise dating of the whole complex. Presented here are the first results of pollen analyses, plant macro-fossil analyses, and identification of wood as a contribution towards the reconstruction of the mammoth's environment.

2. The site

Niederweningen is situated in the upper Wehn valley NW of Zürich at about 450 m a.s.l. (Fig. 1). The steep slopes of "Lägern", the most eastern ridge of the Jura Mountains (869 m a.s.l.), form the southern boundary of the valley. The hills in the N of the site (670 m a.s.l.) consist of Molasse and are covered by banks of Nagelfluh (Deckenschotter). The end-moraines of the last glaciation close the valley to the east, and the Würmian ice did not reach the mammoth site. The valley bottom is filled with Pleistocene sediments.

The mammoth skeleton 2003 was found about 100 m west of the already known mammoth hole of 1890/1891 (Fig. 2). The stratigraphic situation at the site 2003 was as

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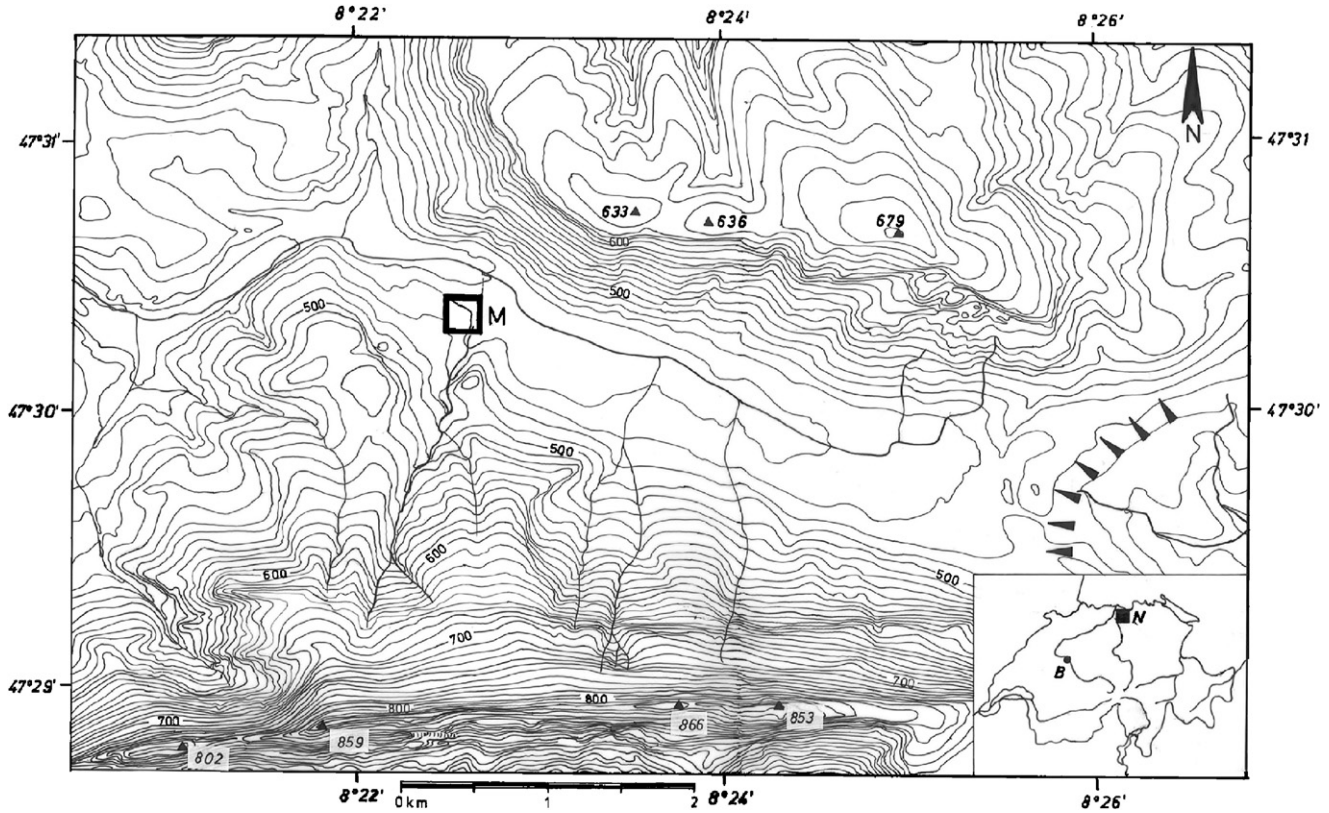


Fig. 1. Topographical map of the mammoth site (M) at Niederweningen and the moraines of LMG closing the valley in the E. Equidistance is 10 m.

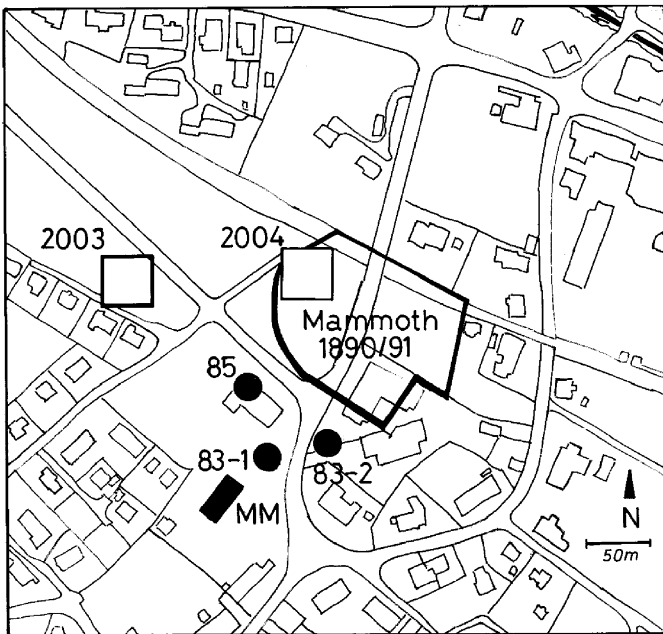


Fig. 2. Overview map of Niederweningen showing the position of the mammoth hole (1890/1891), excavation sites of 2003 and 2004, positions of the drilling sites KB83-1, KB83-2 and KB85, and the mammoth museum (MM) (modified after Furrer et al., 2007).

covered by more than 1 m of silt and sandy gravel, interpreted as alluvial deposits. The mammoth was embedded in the upper part of the 80–100 cm thick middle peat layer (see Fig. 7 in Furrer et al., 2007).

2.1. Dating

Numerous rests of mammoths are known from Switzerland, but only a few have been dated up to now (Wegmüller, 2002; Furrer and Mäder, 2006). The ages vary between $13,705 \pm 55$ ^{14}C yr BP of the skeleton from Praz-Rodet (VD) and 55–48 kyr BP of the tooth at Gondiswil (LU, Hajdas et al., 2007). The first radiocarbon dates of mammoth bones from the peat of Niederweningen resulted in values of 33–35 kyr BP (Schlüchter, 1994). This contrasts with the results of the first palynological investigations (Welten, 1988), showing that the peat layer was deposited during the Eemian and the Early Würmian. The excavations in 2003 and 2004 provide excellent material for radiocarbon dating on different material (wood, seeds and other plant macro-remains, peat and bones) as well as for luminescence dating. According to these results the middle peat was deposited ca. 45 kyr ago (Hajdas et al., 2007; Preusser and Degering, 2007).

3. Materials and methods

For interdisciplinary studies (pollen, plant macro-fossils, beetles, dating) eleven partly overlapping profiles (covering

follows: the lower part of the excavation section consisted of clayey, silty and partly sandy sediments with three intercalated peat layers. This lacustrine sequence was

76 cm each) were collected by the excavators. To facilitate the determination of the wood remains and to increase the number of samples, larger wood fragments were collected at two additional positions. As a first step, the palaeobotanical investigations focused on the mammoth peat in profiles 8 and 9, both situated in proximity to the skeleton (Fig. 3). A brief sedimentological description and a correlation of these two profiles are given in Table 1 and Fig. 4. For pollen analyses, 72 samples (2–3 cm³ each) were taken from the middle peat at intervals from about 2 cm to a maximum of 10 cm. From this set of samples, 33 samples were prepared for analyses using HF solution (to remove inorganic material) followed by acetolysis (for removing

organic matter). For each sample, 500–1000 pollen grains were analysed and counted at a magnification of 400–1000 \times . For the identification of unknown species, publications by Beug (2004) and Reille (1992–1995) were used as references. Spores of fungi and other non-pollen palynomorphs (NPP) were identified after van Geel (1978) and Haas (1996).

For analysing plant macro-fossils, nine samples with a volume of about 400 ml and a maximum thickness of 10 cm were taken from the two profiles. After determining weight and exact volume the samples were charged with water through different meshes (mesh sizes of 4, 2, 1, 0.5, and 0.2 mm). The residual on the meshes of 4, 2, 1, 0.5 mm was completely investigated under the stereomicroscope. The residual on the 0.2 mm mesh was only partly analysed. The content of this particular mesh was extrapolated to the whole sample, which causes an overrepresentation of some plant species. Fruits and seeds were identified under the stereomicroscope by comparison with a collection of recent species and using reference literature (Katz et al., 1965; Jacomet et al., 1989; Jacquat, 1988).

For wood analyses hand cut sections (transversal, radial and tangential sections) were made with razor blades. These sections were identified under the stereomicroscope Olympus BX-60 (objectives UMPlanFl 5 \times , 10 \times , 20 \times and Ach 40 \times) in the Laboratory of Quaternary Woods by comparison with recent material and using an electronic key (www.woodanatomy.ch). Altogether, 368 wood fragments were determined from 28 samples and sub-samples.

The results of pollen analyses are presented as pollen diagrams (Figs. 5 and 6). Combined in pollen sum 1 (at least 500 pollen grains, in general, more than 700/sample) is the pollen of all trees and shrubs (arboreal pollen, AP) and of terrestrial herbs (non-arboreal pollen, NAP). The pollen of all water plants and spores of fern and mosses are expressed referring to pollen sum 1. Pollen sum 2 represents

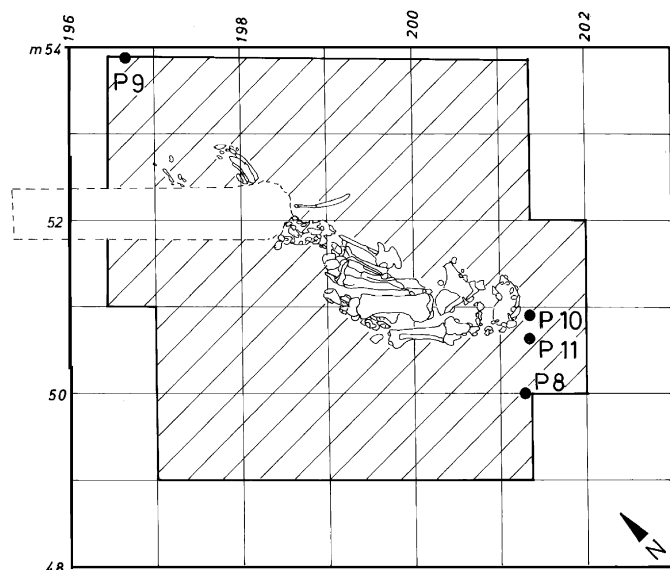


Fig. 3. Map of the excavation area 2003 presenting the position of the skeleton and the profiles 8 and 9 (modified after Kantonsarchäologie Zürich).

Table 1
Description of the sediments of profiles 8 and 9

Elevation (m a.s.l.)	Description
Profile 8	
454.94–454.88 m	Dark brown grayish, silty peat
454.88–454.75 m	Moss peat
454.75–454.32 m	Dark brown, well decomposed peat with wood
454.32–454.25 m	Transition from irregularly laminated dark brownish silt towards silty sand
454.25–454.19 m	Grayish–yellowish silty sand with pebbles
Profile 9	
454.18–454.13 m	Sandy, gray-brown silt with high organic content
454.13–454.07 m	Yellowish-brown coarse sand
454.07–454.03/035 m	Dark-brown, decomposed peat with some sand
454.03/035–454.06/035 m	Dark-brown, decomposed peat with silt and sand layers
454.06/035–454.00 m	Reddish-brown, decomposed moss peat
454.00–453.96 m	Dark-brown, decomposed moss peat with few wood remains
453.96–453.83 m	Dark-brown, decomposed moss peat with few wood remains and silt and sand layers
453.83–453.73 m	Dark-brown, decomposed peat
453.73–453.49 m	Dark-brown, decomposed peat, slightly sandy
453.49–453.42 m	Grey-brown, sand and silt

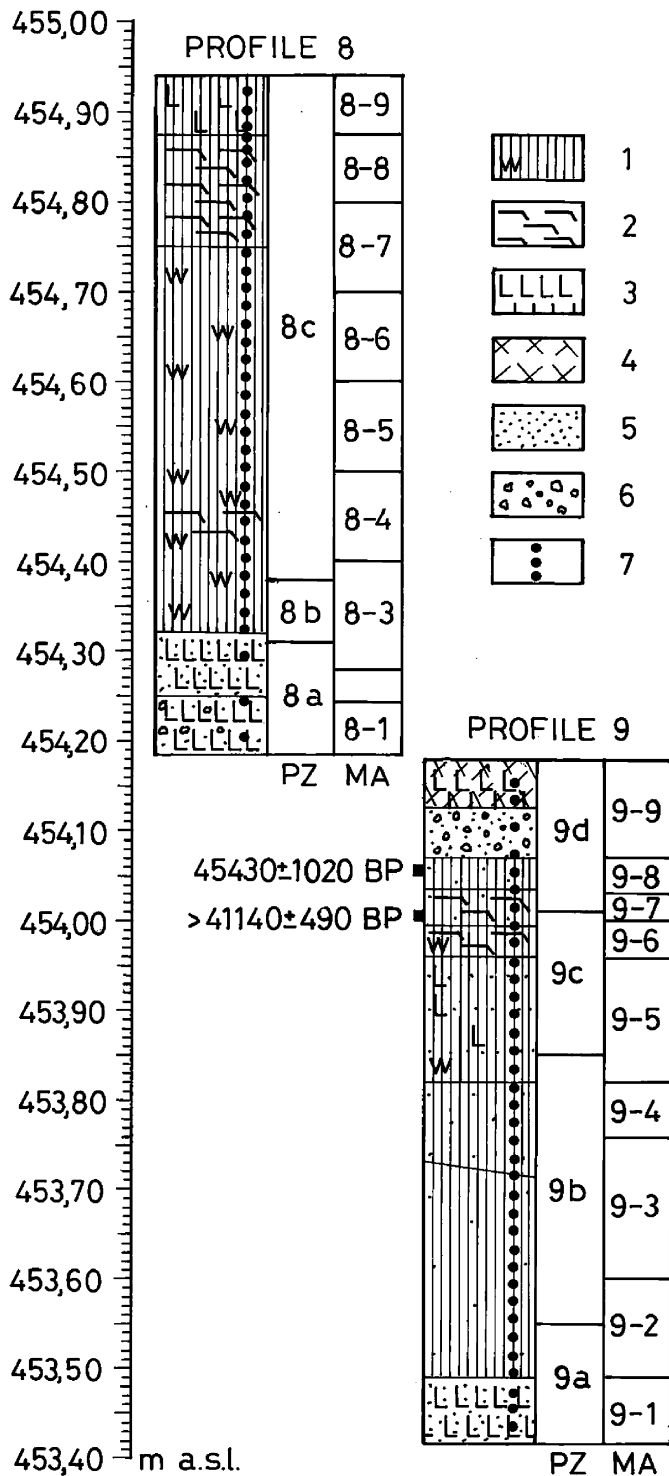


Fig. 4. Depth and sediment correlation of the profiles 8 and 9 and the position of the radiocarbon dates. Legend: 1 Cyperaceae-peat, partly with wood, 2. moss peat, 3. silt, 4. high content of organic matter, 5. sand, 6. gravel, 7. pollen samples, MA samples for plant macro remains, PZ pollen zones.

the pollen of AP, NAP and of all wetland plants. In addition to water plants, all NPP (flatworms, rotifers, amoebae, algae, etc.) refer to this sum. Stomata of conifers appear as counted number per sample. The pollen

diagrams are subdivided into different pollen zones (PZ) reflecting samples with a similar pollen composition. These diagrams were calculated and have been drawn using the programs TILIA 2.0.b.4 and TGView_2.0.2. The results of plant macro-fossil and wood analyses are presented in Tables 2–4.

4. Results

4.1. Reconstruction of the vegetation pattern

The conservation of the different botanical remains is variable. The fruits and seeds are preserved quite well but their eroded aspect, probably due to the acidic environment of embedding, impedes in most cases identification to species level. The preservation of the pollen grains is good. In some samples, however, the pollen concentration is very low. The wood samples are mainly remains of branches and twigs, and several slivers of *Picea* are present. All wood fragments are biologically strongly decomposed, some are compressed. The microstructures are not always recognisable because the already decomposed wood pieces were dried and shrunk several times after sedimentation. Frequently, the presence of pyrite needles made it impossible to cut the wood remains. Since typical aspects of long distance transported wood are missing, the trees apparently have grown not far from the site of discovery.

4.2. Regional vegetation pattern

Reconstruction of the regional vegetation pattern is mainly based on pollen analysis (Figs. 5a,b and 6a,b). Four major periods of vegetation are reflected in the peat.

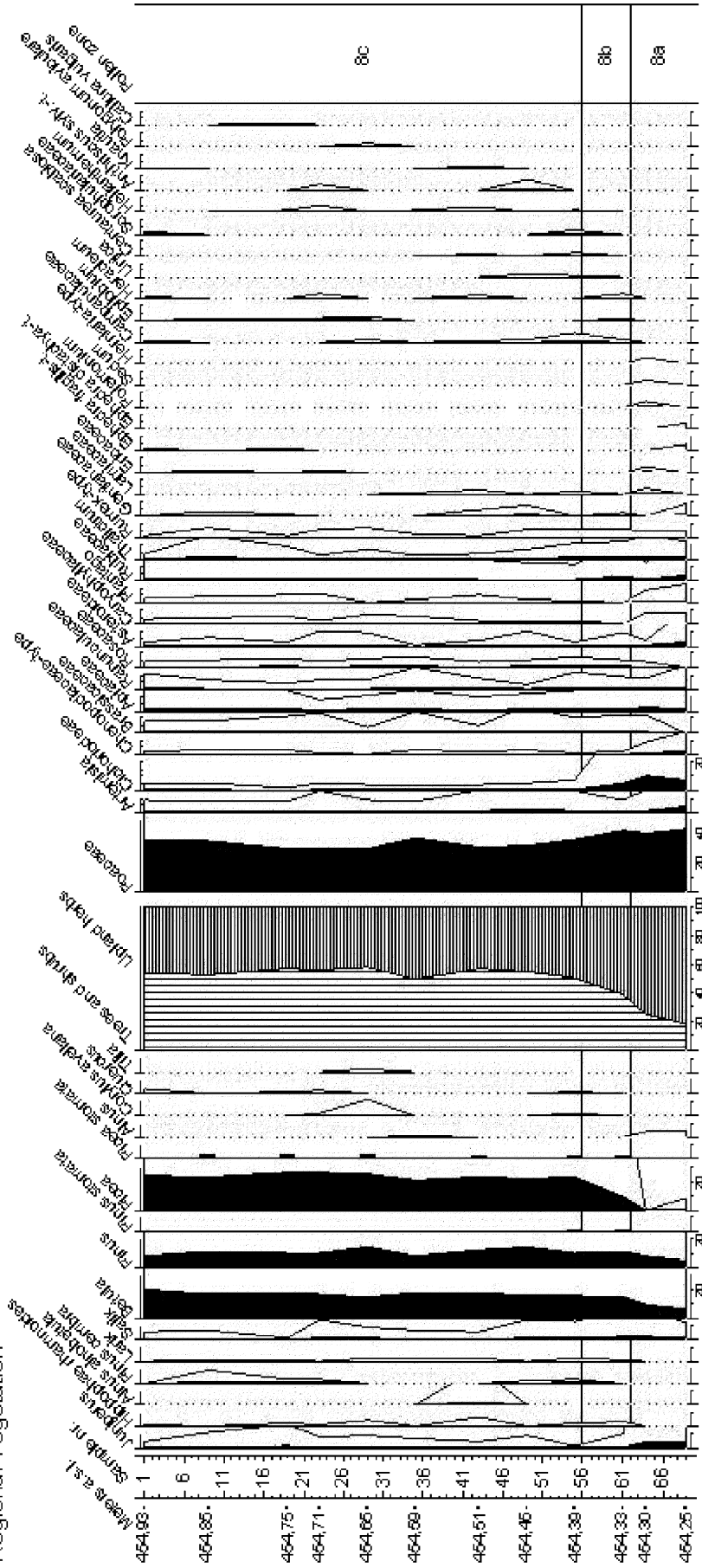
4.2.1. Treeless vegetation

During the onset of peat growth, the amount of tree pollen (AP) is very low and consists of *Juniperus*, *Betula*, *Pinus*, *Salix*, and *Picea* (pollen zones PZ 8a and 9a). Poaceae and Cichorioideae are the dominating herbs. Also abundant are Apiaceae, Rubiaceae, Asteraceae and *Thalictrum*. Remarkable is the presence of *Polemonium*. *Botrychium* and *Selaginella selaginoides* are regularly found. Altogether, these findings represent a pronounced open landscape with sparse growth of shrubs, mainly *Juniperus*, *Betula* and *Salix* and very little *Picea* and *Pinus*. This low percentage of trees and shrubs is interpreted to indicate rather unfavourable climate conditions.

4.2.2. Period of reforestation

During the following period the amount of AP increased indicating reforestation of the valley (PZ 8b and 9b). Beside *Betula*, the main increase is observed for *Picea*. *Larix*, *Pinus cembra*, *Alnus alnobetula*, and *Hippophae* are present for the first time in the pollen spectra of this profile. Poaceae dominate the pollen of herbs. *Artemisia*, Brassicaceae, and Caryophyllaceae are regularly present. Few pollen grains of heliophytes, such as *Armeria*, *Polemonium*,

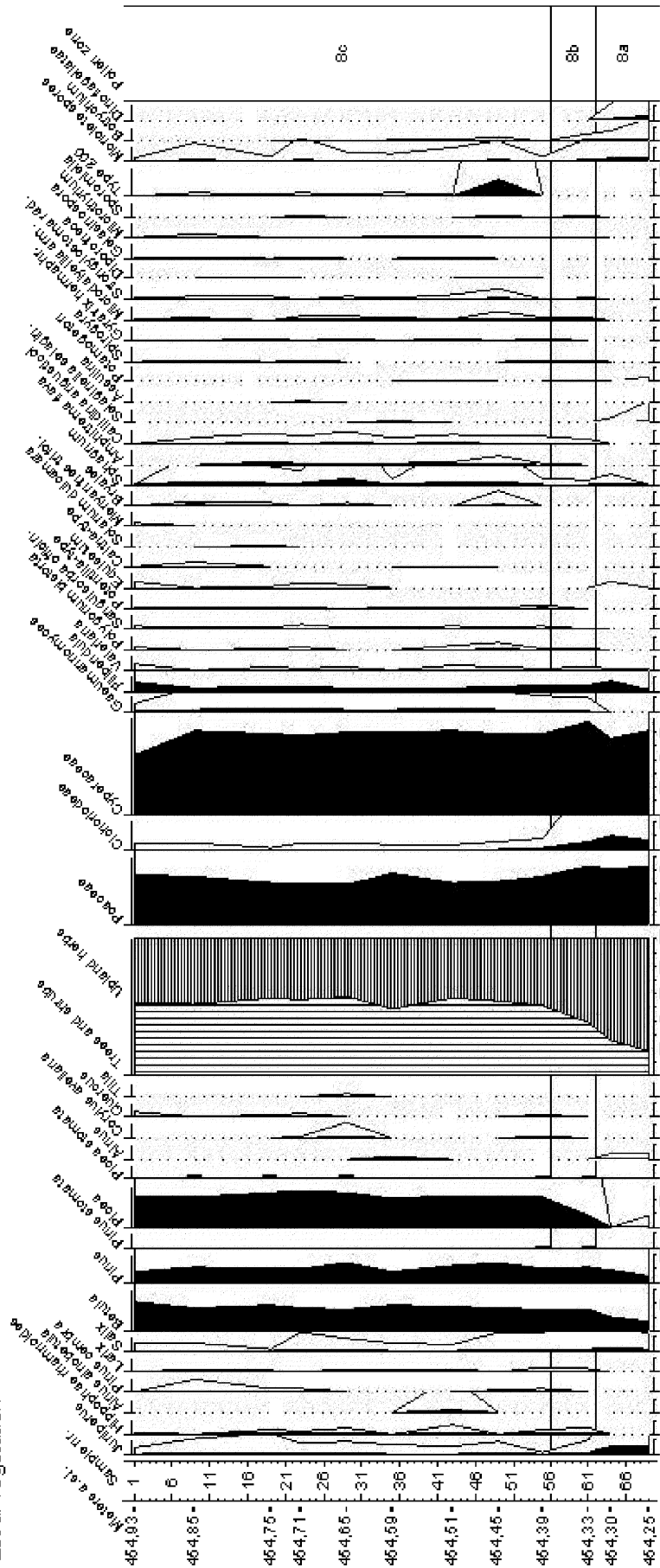
a
 Mammoth 2003 Niederweningen
 Profile 8, Middle Peat
 Regional Vegetation



analysis R. Drescher-Schneider 2004/2005

Fig. 5. Reduced pollen diagram of profile 8: (a) regional vegetation development, (b) mire vegetation.

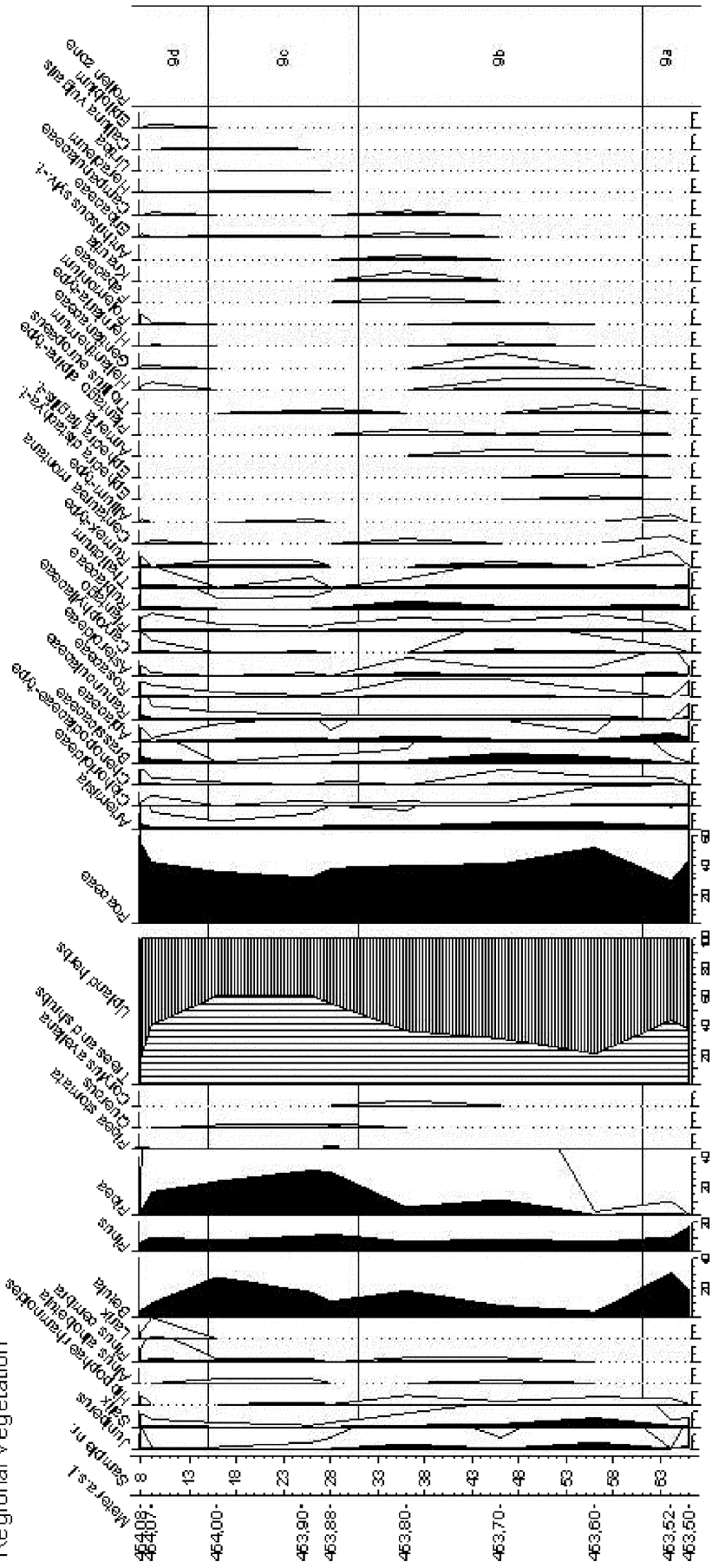
b
 Mammuth 2003 Niederweningen
 Profile 8, Middle Peat
 Local Vegetation



analyses R. Drescher-Schneider 2004/2005

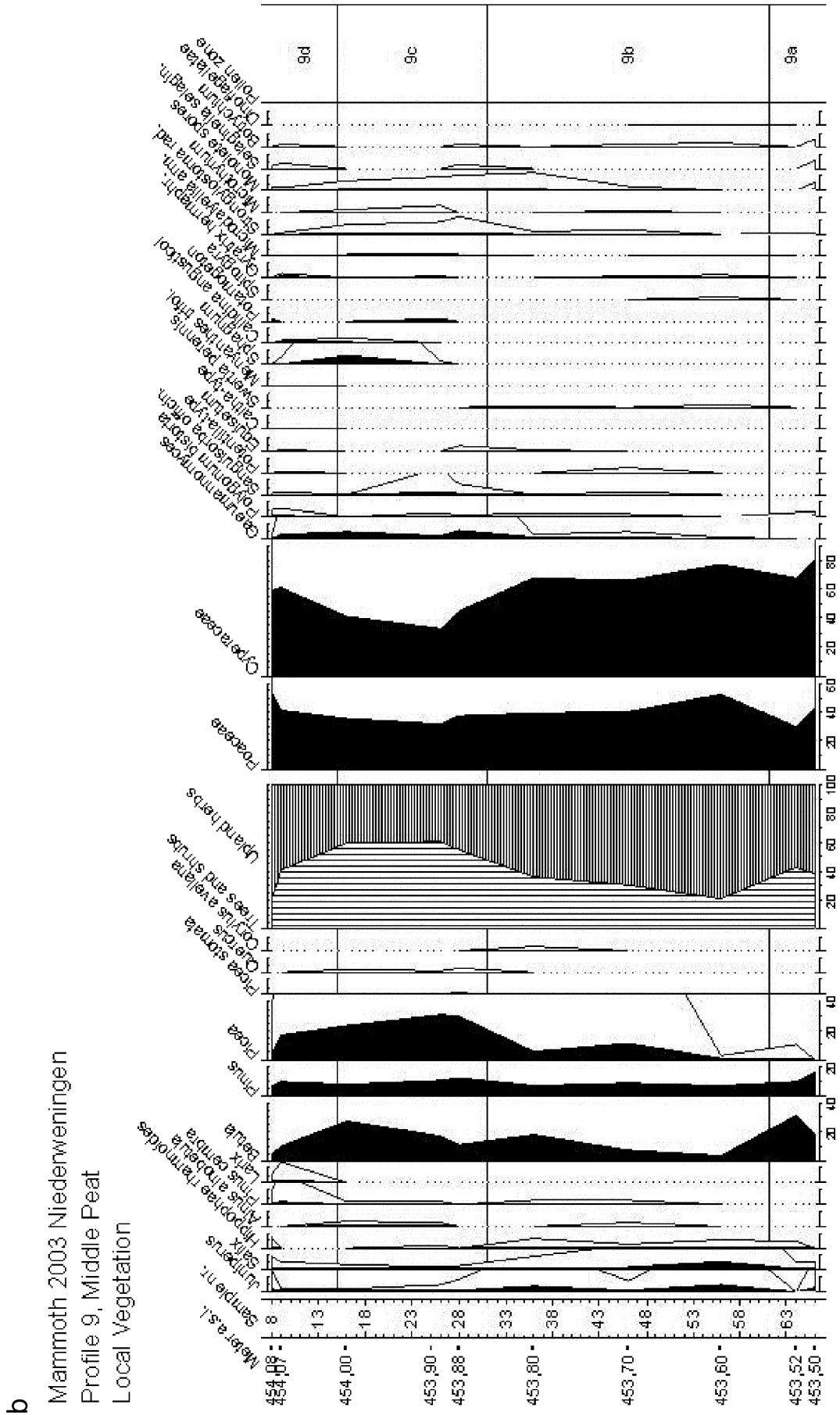
Fig. 5. (Continued)

a
Mammoth 2003 Niederweningen
Profile 9, Middle Peat
Regional Vegetation



analyses R. Drescher-Schneider.2004.02.005

Fig. 6. Reduced pollen diagram of profile 9: (a) regional vegetation development, (b) mire vegetation.



analyses R. Drescher-Schneider 2004/2005

Fig. 6. (Continued)

Table 2
List of the macro-fossil remains from profile 8 / = fragments

Niederweningen: plant macro-fossils of profile 8										
Samples	8.9	8.8	8.7	8.6	8.5	8.4	8.3	8.2	8.1	
m a.s.l.	454.875–454.97	454.80–454.875	454.70–454.80	454.60–454.70	454.50–454.60	454.40–454.50	454.28–454.40	454.25–454.28	454.18–454.25	
Volume fresh (ml)	500	330	340	340	350	350	540	400	390	
Volume saturated with water (ml)	?	300	300	300	300	300	460	300	300	
<i>Submerged vegetation</i>										
Characeae	5									
<i>Floating-leaf aquatic plant community</i>										
<i>Potamogeton</i> sp.	1									
<i>Ranunculus aquatilis</i> agg.	3									
<i>Mire vegetation</i>										
<i>Carex</i> sp.	5	129	125	123	127	65	106	2	4	
cf. <i>Carex</i> sp.	1					3				
Cyperaceae	3		4	3		34	1			
cf. Cyperaceae	13				1	16	24			
<i>Diff. types of meadows</i>										
cf. Asteraceae	1		4	6		8	3			
cf. Dipsacaceae							1			
cf. Poaceae	10				2		3			
cf. <i>Potentilla</i> sp.							3			
cf. Ranunculaceae						1				
<i>Trees</i>										
<i>Betula</i> sp., fruits	3		3	5		2	6	2	1	
<i>Betula</i> cf. <i>nana</i> , leaves	/18		/7	/10	/9	/3				
<i>Picea</i> sp./ <i>Pinus</i> sp.			1	1						
Phnaeeae, needles	1						6		17	
<i>Shrubs, edges of forests</i>										
<i>Rubus fruticosus</i> group				1		1	1			
<i>Rubus idaeus</i> group						2	15	10	2	
cf. <i>Urtica</i> sp.										
<i>Mosses</i>										
Bryophytes	/5	/59	/55	/23	/17	/11	/46	/1	/4	
<i>Others</i>										
Indet. rests	14		8	1	4	1	6	2	2	
Indet. (cf. <i>Equisetum</i> ?)			2	4						
cf. radicles/twigs		14	9		19	20	36	34		
cf. Coenococcum?	4	/9	6	/11	3	/7	/4			
cf. epiderme	5	3	3	17	6	5	15		1	
Varia	/21	/18	/5			/20	/114	/127	/20	
Wood		3	3						1	
Charcoal									1	
<i>Fauna</i>										
Tooth		16	5	6	4	7	7		1	
Insects: adult		26	36	17	21	11	39	13	11	
Insects: pupa										
<i>Inorganic rests</i>										
cf. oere						6	21	1	75	
Silex	9	3	5	8	4	6	21	11	1	
Total	100	302	292	236	220	223	457	203	139	

Table 3
List of the macro-fossil remains from profile 9

Niederweningen: plant macro-fossils of profile 9										
Echantillon	9.9	9.8	9.7	9.6	9.5	9.4	9.3	9.2	9.1	
Alt. (m)	454.07–454.125	454.04–454.07	454.00–454.04	453.96–454.00	453.82–453.96	453.76–453.82	453.60–453.76	453.49–453.60	453.41–453.49	
Description (d'après Drescher-Schneider)	Gelblich-bräunlicher Kies	Schwarzbrauner, gut zersetzter Torf (mittlerer) mit wenig Sand	Rotbrauner, gut zersetzter (Moos)-Torf	Schwarzbrauner, gut zersetzter Torf (mittlerer) mit Holz	Schwarzbrauner, gut zersetzter Torf (mittlerer) mit Holz/Schluff- und Sand/Schwemmungen	Schwarzbrauner, gut zersetzter, leicht sandiger Torf (mittlerer)	Dunkelbrauner, gut zersetzter, leicht sandiger Torf (mittlerer)	Dunkelbrauner, gut zersetzter, leicht sandiger Torf (mittlerer)	Grazbrauner, sandiger Schluff	
Volume frais (ml)	390	370	500	500	490	400	340	380	200	
Volume sat. d'eau (ml)	300	330	430	450	400	380	300	260	150	
3. <i>Marais à laîches</i>										
<i>Carex</i> sp.	13	62	364	230	175	448	68		2	
cf. <i>Carex</i> sp.					11					
Cyperaceae		1	1	49	1		3			
cf. Cyperaceae			8		63			10		
<i>Scirpus</i> sp.										
4. <i>Prairies s.l.</i>										
cf. <i>Lamiatae</i> (Mentha?)		1							2	
Poaceae										
cf. Poaceae						6				
<i>Viola</i> sp.										
5. <i>Srrate arborescente</i>										
<i>Alnus</i> sp.			1							
<i>Betula</i> sp., akènes		1	32	8	4	17				
<i>Betula</i> sp., écaille										
<i>Betula</i> cf. <i>nana</i> ?, feuilles		/26								
<i>Picea</i> sp./ <i>Pinus</i> sp.			7	2	4	110	14			
cf. <i>Picea</i> sp., aiguille					6					
6. <i>Buissons, ourlets forestiers</i>										
cf. <i>Campanula</i> sp.			1	7		5			3	
cf. Rosaceae										
<i>Rubus</i> groupe <i>idaeus</i>		12								
7. <i>Mousses</i>										
Bryophytes	/1	/35	/473	/55	/77		/3			
8. <i>Autres</i>										
Indét.		7	57	21		21	5		4	
cf. radicales		296	442					20	/88	
cf. <i>Cenococcum</i> ?						/30				
cf. épiderme					45	10				
Varia	1		3	28						
Bois										
Charbons de bois			3	2	18			/22	/9	
9. <i>Faune</i>										
Insectes: adultes	/9	/11	/168	/127	/16	/16	/6	/9		
Insectes: pupes	30	25	31	66	21	25	12	34		
cf. pupes						17				
10. <i>Restes inorganiques</i>										
Silice	37									
Total	91	452	1617	574	441	705	137	97	106	

/ = fragments.

Table 4
List of the wood fragments from position 1 and 4, and from profiles 8 and 9

Found site/profile	Found no.	Sieve fraction (mm)	Determination	Number	Remarks
1	33		Bone	1 ×	Fragment of bone (or tooth)
1	34		<i>Salix</i> sp.	1 ×	
1	105		<i>Picea</i> sp.	1 ×	Cone with seed wing
1	121		<i>Picea</i> sp.	55 ×	17 are splinters of stemwood
			<i>Betula</i> sp.	10 ×	
			<i>Lonicera</i> sp.	4 ×	
			<i>Salix</i> sp.	2 ×	
4	111		<i>Picea</i> sp.	15 ×	
4	113		<i>Picea</i> sp.	1 ×	
4	115		<i>Picea</i> sp.	1 ×	
4	117		<i>Picea</i> sp.	78 ×	4 fragments are slightly charred
			<i>Betula</i> sp.	3 ×	
4	123		<i>Picea</i> sp.	54 ×	8 fragments are slightly charred
			<i>Betula</i> sp.	10 ×	
8.1		1	Bark, indet.	1 ×	
			Fragment of seed skin	1 ×	
			Fragment of bone	1 ×	Charred
			Charcoal, dicotyledonous wood	1 ×	Indeterminable
		1	Charcoal, indet.	1 ×	
			Fragmentes of needles, <i>Picea</i> sp.	2 ×	
		2	<i>Betula</i> cf. <i>nana</i>	4 ×	
			<i>Salix</i> sp.	7 ×	
8.2		2	<i>Betula</i> cf. <i>nana</i>	2 ×	
			<i>Salix</i> sp.	10 ×	
		1	<i>Betula</i> cf. <i>nana</i>	1 ×	
			<i>Salix</i> sp.	10 ×	
		1	Bark, indet.	3 ×	
8.3		4	<i>Betula</i> cf. <i>nana</i>	4 ×	
			<i>Salix</i> sp.	1 ×	
		2	<i>Betula</i> cf. <i>nana</i>	15 ×	
			<i>Salix</i> sp.	7 ×	
		2	<i>Betula</i> cf. <i>nana</i>	6 ×	
			<i>Salix</i> sp.	9 ×	
8.4		4	<i>Betula</i> cf. <i>nana</i>	1 ×	(Not charred)
		4/2	<i>Salix</i> sp.	2 ×	
			<i>Hippophaë rhamnoides</i>	2 ×	
			<i>Betula</i> cf. <i>nana</i>	3 ×	
			<i>Lonicera</i> sp.	1 ×	
			<i>Arctostaphylos</i> cf. <i>uva-ursi</i>	1 ×	
			<i>Rubus</i> sp.	2 ×	
8.7		2	Bark, <i>Salix</i> sp. cf.	3 ×	
		1	Fragmentes of needles, <i>Picea</i> sp.	3 ×	
8.8		4	Bark, <i>Betula</i> sp.	2 ×	
		1	Fragmentes of needles	20 ×	
8.9		4/2/1	<i>Betula</i> cf. <i>nana</i>	2 ×	
			<i>Salix</i> sp.	4 ×	
			<i>Picea</i> sp.	1 ×	
9.1		2	<i>Salix</i> sp.	9 ×	
9.2		2	<i>Betula</i> cf. <i>nana</i>	3 ×	
			<i>Salix</i> sp.	14 ×	
		2/1	Fragmentes of needles, <i>Picea</i> sp.	1 ×	
			Charcoal, <i>Pinus</i> sp.	1 ×	

Ephedra, *Anthriscus sylvestris*-type, *Herniaria*-type, *Knautia*, *Trollius*, and *Botrychium* have been found. The response of trees and shrubs to the improving climatic conditions occurred rather rapidly, despite the fact that the preceding climatic conditions did not allow any larger tree

populations. However, the rather rapid spread implies that *P. cembra*, *Larix* (both indicating relatively continental conditions) as well as *Picea* were probably present as small groups of trees or even solitary specimens at some sheltered positions with more favourable micro-climatic conditions.

With the improving of the climatic situation, these taxa could spread rather rapidly.

4.2.3. Forest tundra

The percentage of AP during this period is between 50% and 60% (PZ 8c and PZ 9c). *Picea* and *Betula* are dominant. *Pinus* barely reaches more than 10%. *P. cembra* and *A. alnobetula* are sporadically found. Shrub vegetation is enriched in taxa: beside *Hippophae* and *Salix*, evidence for the presence of *Lonicera* and dwarf shrubs such as *Arctostaphylos* cf. *uva-ursi* has been found. The sparse presence of pollen of thermophilous trees (*Quercus*, *Tilia*) and shrubs (*Corylus*) is attributed to long distance transport from refugia on the Italian Peninsula or to reworked older material. The spectrum of herbaceous pollen types is rich and ranges from species of tall forb communities such as *Heracleum* and *Thalictrum*, through species of grassland (*Centaurea scabiosa*, Gentianaceae, *Pedicularis*, *Knautia*, *Scabiosa*), to representatives of more open vegetation such as *Helianthemum*, for example.

This part of the profile reflects a landscape with open forest of *Picea*, *Betula* and *Larix* as found presently at the transition from boreal forest towards treeless tundra e.g. Yakutia (eastern Siberia, Fig. 7). This transitional zone is characterised as forest tundra (Walter and Breckle, 1986), in this particular case as forest tundra with *Picea*. *P. cembra*, *Larix* and *A. alnobetula* were probably present at the upper slope of the surrounding hill ridges (Egg Hill to the north and Lägern Hill to the south). It would be expected that the south-facing hill slope was most likely more densely forested than the slopes exposed to the north. Furthermore, it is assumed that the tree line on the north exposed steep slopes of Lägern hill was at a lower elevation compared to that on the south exposed slopes.

4.2.4. Period of decreasing tree vegetation

The upper part of the pollen diagram of profile 9 (PZ 9d) reflects the end of the forest vegetation. The prominent decrease of tree pollen from about 60% to 20% (PZ 9d) is



Fig. 7. Example of a landscape in the transition area of forested tundra to treeless tundra from Yakutia (Siberia, Photo W. Schoch).

mainly due to the disappearance of *Betula* and *Picea*. The presence of *P. cembra*, *Larix* and *Juniperus* apparently increases, but this is probably due to a lowering of tree line towards the investigated site. Herb vegetation including *Artemisia*, Chenopodiaceae, Brassicaceae, *Thalictrum*, *Helianthemum*, Rubiaceae, *Herniaria*, *Botrychium*, and *Selaginella* became more diverse implying a more open type of vegetation.

4.3. Local vegetation pattern

The local vegetation is reconstructed from both plant macro-remains and wood analyses (Tables 2–4) as well as from the spectrum of herbaceous pollen (Fig. 5b and 6b). The main part of the peat consists of a Cyperaceae-peat. However, at both sections the material changes in the upper part towards an almost pure moss-peat. Although *Sphagnum* spores are regularly found, this layer does not represent a *Sphagnum*-peat (Fig. 8b). A detailed determination of the moss macroremains is in progress. The pollen of Cyperaceae is always high with values between 40% and 80% (referring to pollen sum 2). Although the main part is attributed to *Carex*-type, other parts may represent *Rynchospora*-type (not separated in the pollen diagram due to the uncertainty of determination). Apparently, *Eriophorum* was present within the mire vegetation. A more precise determination of the abundant findings of *Carex* fruits was not possible in the disposal time (Tables 2 and 3). The remains of the parasitic fungus *Gaeumannomyces* (type 126 according to van Geel, 1978) point towards a presence of *Carex paniculata*. Beside fruits of *Carex*, which may belong to *C. paniculata*, larger biconvex as well as trigonous seeds imply the presence of a different *Carex* species (Fig. 8m). Most of the species identified represent wet or at least moist habitats (e.g. *Filipendula* cf. *ulmaria*, *Polygonum bistorta*, *Caltha palustris*, *Sanguisorba officinalis*, *Scirpus* sp. (Fig. 8i), *Valeriana* cf. *dioica*, *Trollius europaeus*, *Viola* sp. (Fig. 8k) are representatives for purple moor-grass meadows (*Molinion coeruleae* W. Koch) and eutrophic wet-meadow communities (*Calthion* Tx.). All of these species are related to nutrient- and base-rich soils.

In contrast, *Swertia perennis* and *Primula farinosa* are related to fens and spring mires (*Caricion davallianae* Klik). *C. paniculata* belongs to communities of macrophytes (*Caricion elatae* W. Koch), which form with *Chara*, *Potamogeton* and *Ranunculus aquatilis* (Fig. 8a,e,j) the transition of overgrown areas to open water. Evidence for oligotrophic, acidic peat bogs is rarely found in the pollen spectrum. Spores of *Sphagnum* are regularly present with low values but it remains unclear if these spores represent explicit raised peat bog species (e.g. *Sphagnum magellanicum*, *Sph. cuspidatum*, *Sph. rubellum*, *Sph. papillosum*, *Sph. cuspidatum* or *Sph. compactum*) as it is impossible to relate the spores to specific species. Only the frequent occurrence of *Amphitrema flava* in PZ 8.3 (Fig. 5b) implies a raised bog character of the site, since this thecamoebaen is exclusively related to the upper peat layers of a raised bog (Streble and

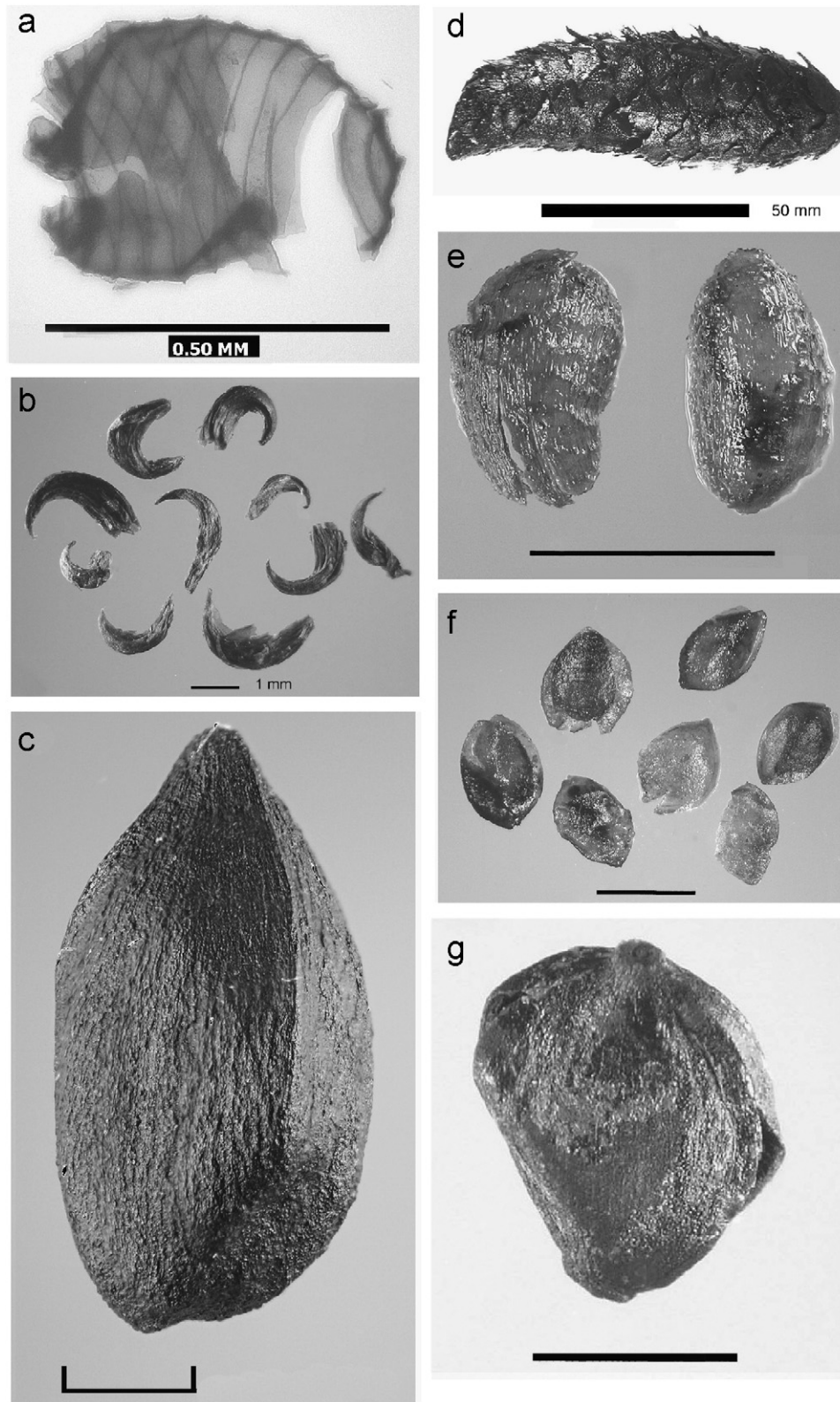


Fig. 8. Photos of the plant macro remains. The black bar represents 1 mm. (a) Characeae, oospore, (b) Bryales, leaves, (c) *Pinus/Picea*, seed, (d) *Picea abies*, cone, (e) *Ranunculus aquatilis* agg., fruit, (f) *Urtica* sp., fruit, (g) *Alnus* sp., fruit, (h) Asteraceae, achenes, (i) *Scirpus* sp., fruit, (j) *Potamogeton* sp., seed, (k) *Viola* sp., seeds, (l) *Rubus idaeus* group, fruit stones, (m) *Carex* sp., trigonous fruits, (n) *Betula* sp., catkin scale, (o) *Betula* cf. *nana*, leaf fragments, (p) *Betula* sp. fruit.

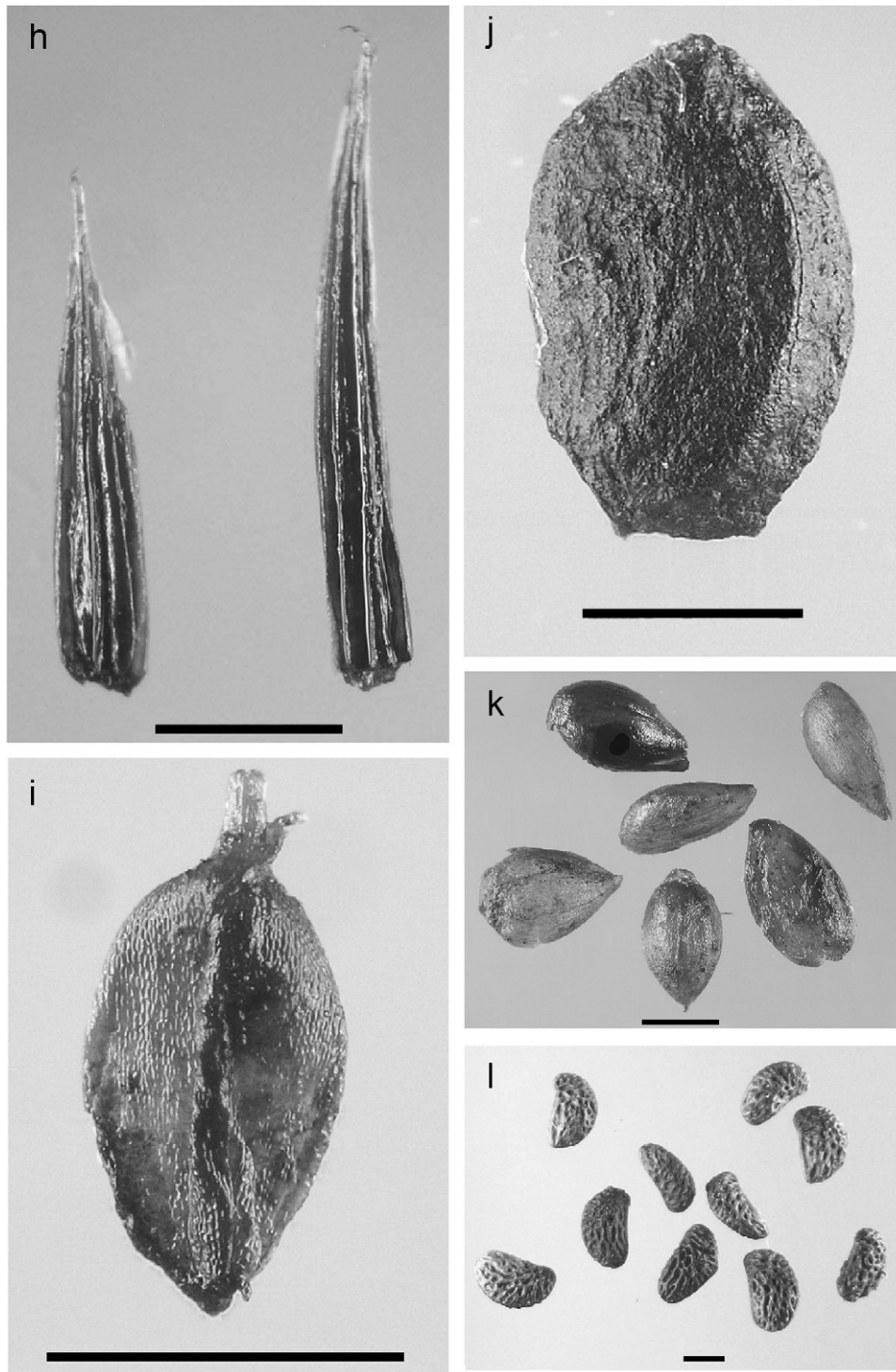


Fig. 8. (Continued)

Krauter, 1973). Only a few pollen grains but several seeds of *Menyanthes* have been found. It was unfortunately not possible to clearly distinguish the *Scheuchzeria* pollen type, but the frequent presence of *Callidina longicollis* (rotifer), which is most frequent in *Scheuchzeria*-peat, points towards its presence. Both *Menyanthes trifoliata* and *Scheuchzeria palustris* either representing pools within the peat bog or communities within the overgrown areas.

Apparently, the mire was rather wet (at least at the investigated site) as indicated by the eggs of *Gyratrix hermaphroditus*, *Strongylostoma radiatum*, and *Microdalyellia armigera* (flatworms—*Neorhabdocoela*).

The spectrum of species hence reflects a complex mosaic of different vegetation types, which presumably covered smaller or larger areas resulting from differences in specific topography, composition of soil, and water availability.

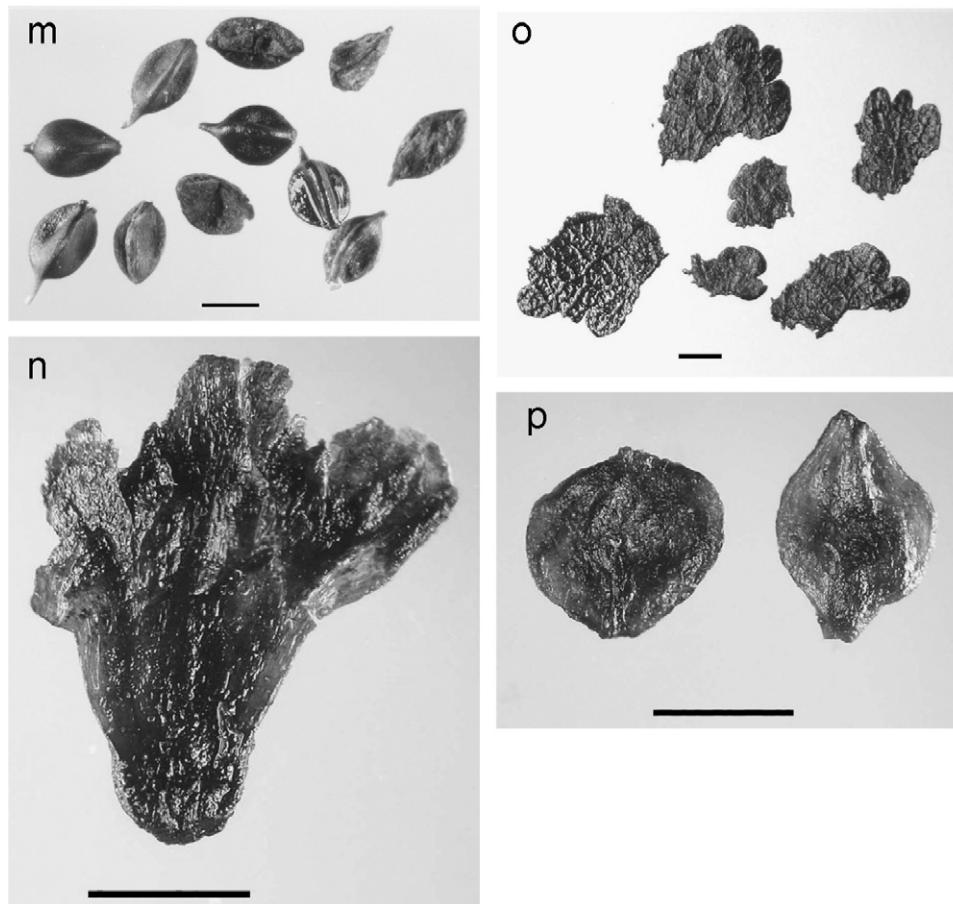


Fig. 8. (Continued)

During the less favourable periods at the beginning and at the end of peat development, only a few remaining trees (fragments of *Picea* needles, Table 2) and some woody remains of *Salix* and *Betula* cf. *nana* are found. The pollen spectrum is characterised by increased percentages of Cichorioideae, Chenopodiaceae, Brassicaceae, and Artemisia. This combination indicates patchy vegetation with a sparse shrub cover and grassland with some subalpine elements (e.g. *Polemonium coeruleum*), but dominated by steppe taxa and species of stony habitats (*Ephedra*, *Sedum*). During the period of better climatic conditions single trees or small groups of trees (mainly *Picea*, 77% and 92% of wood samples of sites 1 and 4 out of the profiles, Fig. 8c, d) on slightly higher position were surrounded by dwarf shrub vegetation with different species of creeping *Salix* (56% of wood fragments of profile 8) and *Betula nana* (32% of wood fragments of profile 8 and leaves, Fig. 8o, p). Neither wood nor fruit remains have yet proved the presence of birch trees (*Betula pubescens* and *B. pendula*), and it appears unlikely that they grew at the mire itself. Due to the difficulties in distinguishing between pollen of *Betula nana* and *B. pendula/pubescens*, such a differentiation has yet not been attempted at the site. On drier habitats, the pollen and macroflora reflects the character of an open *Picea* forest with a species rich herb

layer (*Campanula*, *Plantago alpina*, *C. scabiosa*, *Centaurea montana*, *A. sylvestris*, *Selaginella*, *Botrychium*, etc.), with tall forb communities (e.g. *Lilium* cf. *martagon*, *Thalictrum*, *Pleurospermum austriacum*, *Urtica* cf. *dioica* (Fig. 8f), *Heracleum* and *Rubus* (Fig. 8l).

Charcoal remains and charred bone fragments (Tables 2–4) are of special interest. The charred fragments were irregularly dispersed in site 4 and in the profiles 8 and 9. A weak concentration is evident before and during the reforestation period (macro samples 8.1, 9.2 and 9.5). Very small pieces of silica were found in all samples of profile 8 with a maximum in sample 8.1. According to archaeological expertise, the small pieces of chert are not convincing arguments of human activities at Niederweningen (Furrer et al., 2007) and there are other explanations for its presence. Firstly, the northern slope of Lägern is formed partly by the Late Jurassic Wetting Limestone, from which silica pieces are well known. These pieces can be easily transported by heavy precipitation and deposited on the peat surface. Secondly, no cuts or striations attributed to silica have been discovered on the mammoth bones (Furrer et al., 2007). Thirdly, the Moustérien culture reached its largest development between 50,000 and 40,000 yr BP. In Switzerland the Moustérien sites are rare and concentrated in the Northern Jura Mountains and the

area around Basel. No sites are known from the north-eastern Swiss lowlands (Le Tensorer, 1994).

Due to the lack of indicator species it is impossible to either reconstruct mean annual temperature or temperature of the warmest month. Evidence for relatively warm summer temperatures is given not only by the presence of trees (summer temperature $> 10^{\circ}$), but also by *S. radiatum*, which according to Haas (1996) depends on water temperatures during summer between 10–23 °C. In the investigated sediments the presence of *Strongylostoma* is restricted to the *Picea*-Interstadial.

Investigation of the peat at two different sites reveals that it is in both cases the same type of mire, but the initial phase, the speed of peat growth and its final phase are different. Although such phenomena have been often reported before (e.g. Beug et al., 1999), the large differences (PZ 8.2 comprises c. 7 cm, but PZ 9.2 c. 30 cm) within a relatively short distance (Sections 8 and 9 are at a distance of about 5.8 m) are surprising and are probably not explained by differential humification and differential compression of the peat alone.

5. Chronostratigraphic position of the mammoth peat

The horizon associated with the mammoth remains found in 2003 reflects interstadial conditions with peat growth and *Picea* forests intercalating stadial lake deposits. There is no indication for a presence of thermophilous trees (*Quercus*, *Tilia*, *Fraxinus*, *Ulmus*, *Corylus*, *Abies*, *Alnus*, etc.) in the area beside a few pollen grains that result from long-distance transport or reworked material. Beside the evidence discussed here, there are three more cores available from the area of the former mire at Niederweningen (Fig. 2). Palynological analysis from cores KB83-1 and KB83-2 were published by Welten (1988). Schlüchter (1988) investigated KB-85 and compared his geological observations with those of Welten (1988), but without palynological analysis. The two cores from 1983 both contain a > 2 m thick peat layer, which is in KB83-1 interrupted by a thin layer of silt and sand. Welten (1988) correlated both peat layers with the early Eemian and the Early Würmian. The part of the sequence attributed with the Eemian is dominated by closed forest with *Abies* and *Picea* (30–40% of *Abies*) with a high content of *Alnus* during the initial phase. *Quercus*, *Tilia*, *Ulmus*, *Fraxinus*, *Corylus*, and *Carpinus* are more-or-less constantly present. During the part of the peat correlated with the Early Würmian, *Corylus*, *Betula* and mixed oak forest taxa were still abundant and the forest had a more open character than during the Eemian (see also Wegmüller, 1992; Müller, 2001). The site of 2003 is about 120 m distant from KB83-1 and reflects an open population of *Picea* without any trace of *Abies*, *Carpinus* and the other thermophilous taxa. It is hence excluded that the finding horizon of 2003 was formed at the same time as the peat layers described by Welten (1988). A short phase of dominance of *Picea* together with *Betula*, *Pinus* and *Larix* along with low values of *Alnus* and

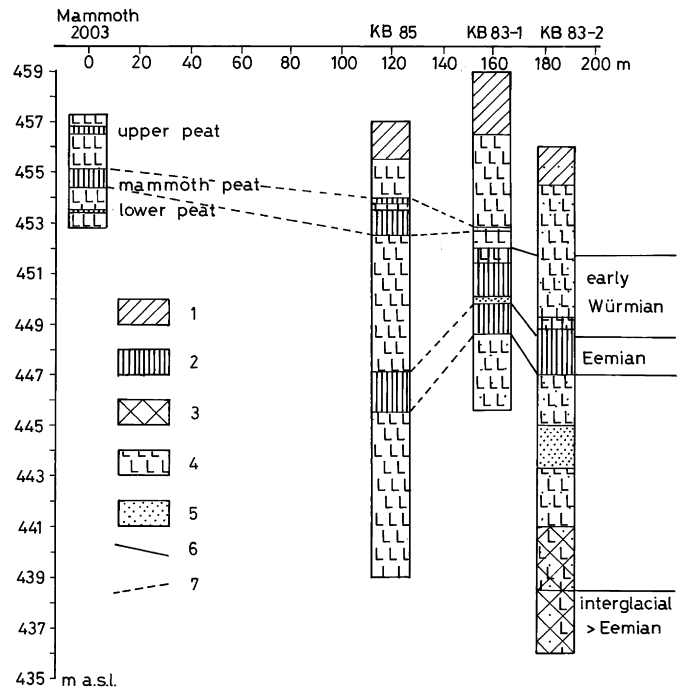


Fig. 9. Correlation of the mammoth sequence with the drillings KB85, KB83-1 and KB83-2. Legend: 1. soil complex, 2. peat, 3. organic lacustrine sediments, 4. silt and clay, 5. sand, 6. sure correlation, 7. supposed correlation.

Corylus (DA 14 of Welten 1988) is present in an organic rich silt layer within KB83-1. According to the pollen assemblages, this *Picea*-Interstadial may be an equivalent of the interstadial of the mammoth horizon of 2003 (Fig. 9). In KB83-2 this part of the sequence is missing, probably due to erosion by a local stream coming down from wither Stüdlern or Guggach Hill (Schlüchter, 1994). It is difficult to exactly correlate *Picea*-Interstadials with a certain period of time due to the lack of specific indicator species (e.g. Gröger, 1996; Wegmüller, 1997). In the upper part of the main peat horizon of the Gossau-Interstadial-Complex (DA 4, Schlüchter et al., 1987) a similar interstadial as at Niederweningen has been identified. Dating of this horizon (radiocarbon: c. $40,920 \pm 1120$ uncal. yr BP; $^{230}\text{Th}/\text{U}$: $47,800 \pm 6000$ yr BP; luminescence: $< 50,000$ yr BP; Preusser et al., 2003) agree quite well with the age of $45,430 \pm 1020$ yr BP from Niederweningen (Hajdas et al., 2007; Preusser and Degering, 2007).

6. Conclusions

The middle peat horizon reflects the development of vegetation within the Wehn Valley during an interstadial, which starts with a period of reforestation, leads towards forest tundra with *Picea* with subalpine grassland vegetation and finally a period of climatic deterioration. During its optimum, vegetation was similar to that at the present timberline with relatively warm summers and snow-rich cold winters and a reduced vegetation growth period. The development of the mire within the valley was caused by

the overgrowth of a lake, which led to a complex pattern of different fen types and raised bog-like plant communities. Different dating methods resulted in an age of about 45 kyr for the mammoth peat and position it within MIS 3.

Pollen analyses reveal that several peat layers of different ages and distributions are present in the Wehn Valley. This makes the reconstruction of stratigraphic relationships in the sedimentary basin of Niederweningen rather difficult. The vegetation development in the Swiss Midlands during the period between the second Early Würmian Interstadial (Ufhusen according to Wegmüller, 1992) and the Late Glacial is still inadequately known. Further construction work near the mammoth hole may provide new pieces for an overall reconstruction of past environmental conditions, which, however, will most likely be reconstructed in the course of a larger future scientific research project.

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