

Vegetation and environment in and around the Reinberg basin (Vorpommern, NE Germany) during the Weichselian late Pleniglacial, Lateglacial, and Early Holocene

PIM DE KLERK^{1,2}, HENRIK HELBIG^{1,3} and WOLFGANG JANKE¹

¹Geographical Institute, Ernst-Moritz-Arndt-University, Friedrich-Ludwig-Jahnstraße 16, D-17487 Greifswald, Germany

²Present address: Staatliches Museum für Naturkunde Karlsruhe, Erbprinzenstraße 13, D-76133 Karlsruhe, Germany; e-mail: pimdeklerk@web.de

³Present address: Landesamt für Geologie und Bergwesen Sachsen-Anhalt, Köthener Straße 34, D-06118 Halle (Saale), Germany; e-mail: helbig@lagb.mw.lsa-net.de

Received 24 January 2008; accepted for publication 20 October 2008

ABSTRACT. Combined palaeoecological and sedimentological analyses of a core from a kettle-hole in Vorpommern (NE Germany) allow the reconstruction of the interaction between vegetation and environment during the Weichselian late Pleniglacial, Lateglacial, and Early Holocene. A humus-containing soil horizon (Reinberg horizon) occurs in the upper part of Pleniglacial sand. This humus formed in a local environment of shallow wet ponds and low dry mineral mounds. Water levels were generally rather low. Rising water levels at the beginning of the Lateglacial drowned this environment and a lake formed. The vegetation development shows a phase with an open regional vegetation (Oldest Dryas or earlier part of the Meiendorf), a period with prominence of *Hippophaë* (Bølling or later part of the Meiendorf), and a subsequent second phase with a more open regional vegetation (Older Dryas). The sediment parameter, together with the reconstructed vegetation, point at a gradual shift to a more humid climate during these vegetation phases. Deposition of CaCO₃ ceased during the *Hippophaë* phase. During the Lateglacial *Betula/Pinus* forest phase (Allerød) forests dominated the dry grounds. Soil erosion had largely stopped and organic sediments were deposited. A prominent pollen fluctuation around the Laacher See tephra shows a minor vegetational and environmental reaction on the eruption of the Laacher See volcano. Silicate input by the tephra favoured diatom populations to expand and prohibited solution of dead diatoms. Open vegetation phase III (Younger Dryas) shows a tripartite opening-up of the regional vegetation. The vegetation was denser and soil erosion was less severe than during the early vegetation phases of the Lateglacial. At the transition to the Holocene, a prominent lowering of water levels caused destruction and/or removal of the upper Lateglacial sediments. After water levels rose again, a peatland developed in the basin.

KEY WORDS: palynology, palaeo-ecology, Weichselian late Pleniglacial, Weichselian Lateglacial, Lateglacial/Holocene transition, NE Germany

INTRODUCTION

Although currently a great number of pollen diagrams from NE Germany covering the Weichselian Lateglacial are available (cf. overview of Kaiser 2002, De Klerk 2002, 2008), most of these studies focus solely on the reconstruction of vegetation history and hardly concentrate on a reconstruction of vegetation in relation to the development of the

abiotic landscape. Integrated geomorphological, palynological, diatomological, and macrofossil analyses were carried out in the basin Reinberg in Vorpommern (Figs 1, 2) in order to reconstruct an integrated palaeoenvironmental development.

The Reinberg basin was originally selected to investigate Lateglacial and late Holocene

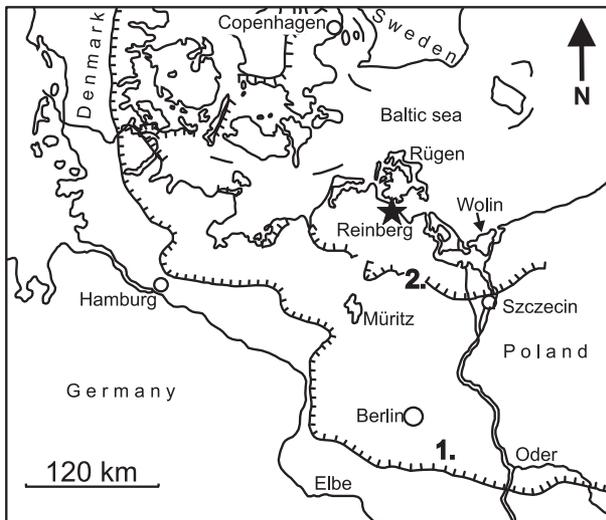


Fig. 1. Location of the Reinberg basin (N Vorpommern, NE Germany) in relation to: 1: maximum extent of the Weichselian inland ice, and; 2: maximum extent of the Mecklenburgian glacial advance

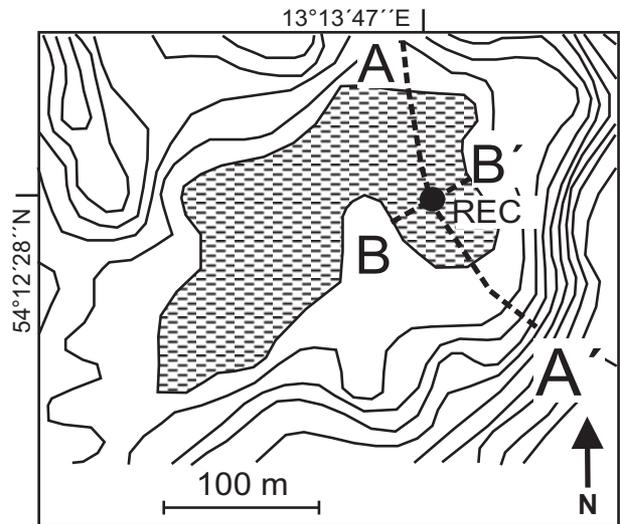


Fig. 2. Map of the Reinberg basin. Indicated are the positions of the lithological cross-sections (Fig. 3) and the location of the analysed core Reinberg C (REC)

slope erosion processes (Helbig 1999a, b, Helbig et al. 2002). Palynological analyses with a low temporal resolution were carried out in order to date the sediments coarsely (Helbig 1999a). These showed a pollen record typical for the late Weichselian Pleniglacial (*sensu van der Hammen 1951*) in a humus layer on top of Pleniglacial basin sands, named “Reinberg horizon”. (De Klerk et al. 2001). This triggered new integrated palaeoenvironmental research (De Klerk et al. 2001, in press, Helbig & De Klerk 2002, De Klerk 2008).

The present paper presents a reconstruction of the interaction between vegetation and the abiotic palaeoenvironment in and around

the Reinberg basin during the Weichselian late Pleniglacial, Lateglacial, and Early Holocene.

STUDY AREA

The surroundings of the „Reinberg” basin (Figs 2, 3) show a particular pronounced relief, in contrast to the typical (slightly) undulating till plains of Vorpommern. The basin has no inlet or outlet and consists of several sub-basins originating from the thawing of buried dead-ice (Janke & Janke 1970, Klafs et al. 1973, Kalettka 1996).

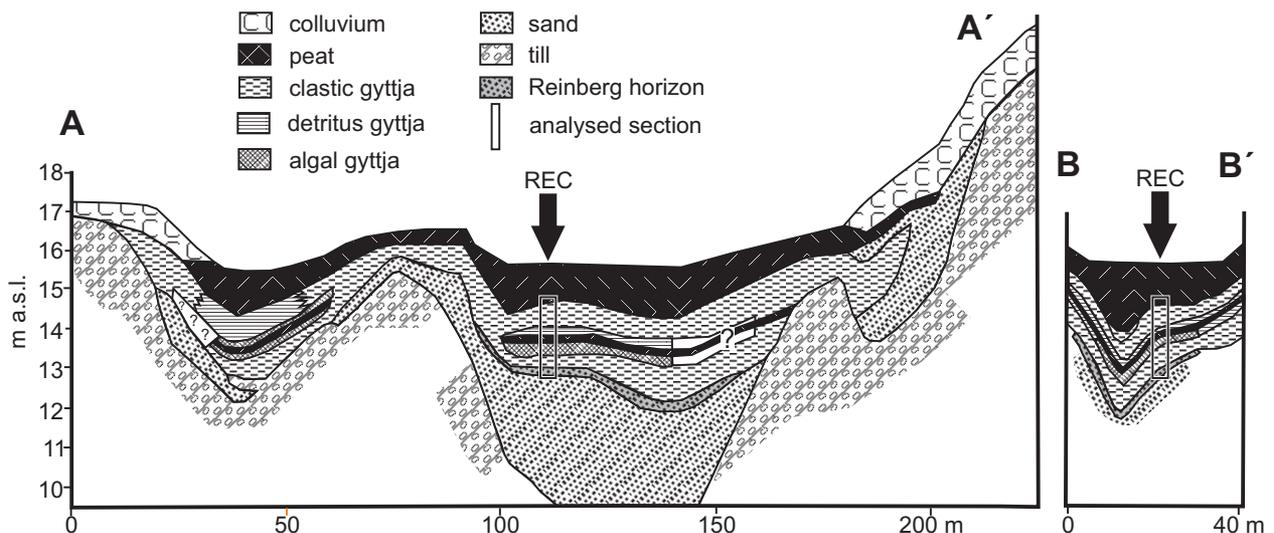


Fig. 3. Cross-sections A–A’ and B–B’ through several subbasins of the Reinberg study area. Indicated is the position of core Reinberg C (REC)

The NW-SE cross-section A-A' (Fig. 3) cuts through three sub-basins (referred to as northern, middle, and southern sub-basin), which are separated by mineral ridges. The SW-NE cross-section B-B' (Fig. 3) only crosses the middle sub-basin. Core Reinberg C (REC) originates from the intersection of both cross-sections. The middle sub-basin has a size of approximately 40 × 50 m and has at its base Pleniglacial basin sands of which the maximum depth could not be determined. In the top few decimetres of the sand a humus-rich fossil Ah-horizon occurs, called Reinberg horizon. The sand is covered by (bottom to top) sand-silt gyttja/silt-sand gyttja, algal gyttja (with the Laacher See Tephra [LST] in its upper part), a thin layer of brownmoss peat, detritus gyttja, a layer of sand-silt gyttja/silt-sand gyttja, and finally brownmoss peat and brownmoss-Cyperaceae peat.

The slopes of the basin (Helbig 1999a, b, Helbig et al. 2002) – which reach up to 20–28 m a.s.l. – consist of pedologically modified till containing (top to bottom) a brownish-weathered earth horizon, a clay-eluvation horizon, and a clay illuvation horizon. Decalcification reaches up to 3 m depth. The slopes show clear traces of erosion with subsequent deposition of colluvial material along the basin margins.

RESEARCH METHODS

CORING METHODS

Core REC was derived with a so-called “Usinger corer” (Livingstone corer modified by H. Usinger). Corings for the lithological cross-sections (Fig. 3) were carried out with a chamber corer and an open “Rammkernsonde”.

PALYNOLOGICAL INVESTIGATIONS

Palynological samples were taken volumetrically and are referred to as the actual core depth (cm) below surface. A known amount of spores of *Lycopodium clavatum* was added to determine pollen concentrations (Stockmarr 1971).

Sample preparation (Fægri & Iversen 1989) included treatment with HCl, KOH, sieving (120 µm), treatment with HF (clastic samples only), and acetolysis (7 min). Counting was carried out with a Zeiss light microscope type Axioskop with 400 times magnification, larger

magnifications were used for the identification of problematic grains. Pollen clumps were counted as separate palynomorphs (i.e. as one entity, not the individual grains forming the clump were counted).

Although Joosten & De Klerk (2002) and De Klerk & Joosten (2007) proposed to display pollen type names in scientific papers in small capitals in order to clearly distinguish between observed palynomorphological types and inferred plant taxa, on editorial request pollen type names are displayed in normal letters in this paper. Pollen and spore types are identified and named after (f): Fægri & Iversen (1989), (m): Moore et al. (1991), (p): the Northwest European Pollen Flora (Punt 1976, Punt & Clarke 1980, 1981, 1984, Punt & Blackmore 1991, Punt et al. 1988, 1995, 2003). This resulted in a heterogeneous system of pollen type names due to a different use of nomenclatural principles in the pollen morphological works used (cf. Joosten & De Klerk 2002, De Klerk & Joosten 2007). However, we decided to retain the pollen type names identical to those in the relevant pollen morphological literature rather than transforming all names to the pollen nomenclatural conventions of Birks & Birks (1980), since otherwise a defective link between observed pollen morphological types and renamed nomenclatural entities in the pollen diagram seriously confuse the scientific reader. Types not described in the mentioned identification literature are marked with an asterisk (*) and commented upon in Table 1: these morphological entities are named according to the pollen nomenclatural conventions of Birks & Birks (1980) and deviate, therefore, from the previous nomenclature used by De Klerk et al. (2001) and De Klerk (2002). We separate between *Juniperus* type pollen (*sensu* Moore et al. 1991) and *Juniperus*-without-gemmae that might originate from algal or bryophyte spores (cf. Moore 1980). Since the curves of *Juniperus* type (m) and *Juniperus*-without-gemmae are rather similar in pollen diagram REC, it can be assumed that in this case mainly *Juniperus* pollen without clear visible gemmae are included in the latter type. We present nevertheless two separate curves in order to illustrate this conclusion: otherwise, the reader can be left wondering whether such a relationship is actually correct or whether it is biased by non-pollen palynomorphs. Of spores of *Selaginella selaginoides* (*sensu* Moore et al., 1991), single grains

Table 1. Comments on pollen types not identified after the used pollen morphological identification literature

Name	Description
Apiaceae undiff.	All grains that show close morphological resemblance with most pollen types produced by Apiaceae taxa (cf. Punt & Clarke, 1984) which were not - or could not be - further identified. The characteristics were not systematically noted to allow for univocally morphological descriptions.
<i>Betula/Corylus</i>	Grains which most likely belong to the <i>Corylus avellana</i> type (p) or one of the <i>Betula</i> pollen types, but with damages around the pore area of such degree that definite identification was not possible.
<i>Betula</i> undiff.	Grains which, due to folds or damages, could not be attributed to the <i>Betula nana</i> type (p) or the <i>Betula pubescens</i> type (p).
Betuloid type	All grains that show most morphological resemblance with pollen belonging on one of the <i>Betula</i> pollen types of the Quaternary identification keys, but which with certainty belong to another pollen type. No unambiguous morphologically descriptions were made; most likely redeposited pre-quaternary pollen.
Bisaccate undiff.	Bisaccate grains which do not resemble the described bisaccate pollen types in Fægri and Iversen (1989) and Moore et al. (1991); morphological characteristics were not noted to allow for unambiguous description.
<i>Botryococcus</i>	Algae, including several <i>Botryococcus</i> taxa, described by Jankovska and Komarek (2002).
Cerealial undiff.	Grains which, due to folds and/or damages, could not be attributed to the <i>Avena/Triticum</i> group (m) or to <i>Secale cereale</i> (m); grains of the <i>Hordeum</i> group (m) are not included in this type.
Caryophyllaceae undiff.	All grains that show close morphological resemblance with most pollen types produced by Caryophyllaceae taxa (cf. Punt et al., 1995) which were not - or could not be - further identified. The characteristics were not systematically noted to allow for univocally morphological descriptions.
Coryloid type	All grains which show most resemblance with <i>Corylus avellana</i> type (p) pollen, but which with certainty are of another pollen type; most likely redeposited pre-quaternary pollen, of which no unambiguous morphologically description were made.
Ericales undiff.	All grains which show close morphological resemblance with most pollen types produced by Ericales taxa (cf. Fægri & Iversen 1989, Moore et al., 1991) which were not - or could not be - further identified. The characteristics were not systematically noted to allow for univocally morphological descriptions.
Fabaceae undiff.	All grains that show close morphological resemblance with most pollen types produced by Fabaceae taxa (cf. Fægri and Iversen, 1989; Moore et al., 1991) which were not - or could not be - further identified. The characteristics were not systematically noted to allow for univocally morphological descriptions.
Fern sporangia	Arc-shaped, spine-like cells, incidentally incorporating numerous. Monolete spores without perine.
Dinoflagellate cysts	Algae of Pre-Quaternary age, described by Iversen (1936) as <i>Hystrix</i> .
<i>Juniperus</i> -without-gemmae	All grains similar to <i>Juniperus</i> type of Moore et al. (1991), but without clear gemmae. This type may represent certain algal or bryophyte spores (cf. Moore 1980).
Liliaceae undiff.	Monolete reticulate grains with some resemblance with pollen types produced by Liliaceae taxa (cf. Moore et al. 1991) which could not be unambiguously identified.
Monolete spores without perine	All psilate monolete spores, of which the outer coat can be considered to have been lost.
<i>Pediastrum boryanum</i> type	Algal coenobia without holes between the independent cells; might include, identified after drawings presented by Jankovska and Komarek (2002), <i>Pediastrum boryanum</i> var. <i>boryanum</i> , <i>Pediastrum boryanum</i> var. <i>forcipatum</i> , <i>Pediastrum boryanum</i> var. <i>longicorne</i> , <i>Pediastrum integrum</i> and <i>Pediastrum patagonicum</i> .
<i>Pediastrum duplex</i> type	Algal coenobia with holes between the independent cells; might include, identified after drawings presented by Jankovska and Komarek (2002), <i>Pediastrum boryanum</i> var. <i>cornutum</i> , <i>Pediastrum duplex</i> var. <i>duplex</i> and <i>Pediastrum duplex</i> var. <i>rugulosum</i> .
<i>Pinus</i> undiff.	Grains of the <i>Pinus haploxyton</i> type (f) and the <i>Pinus diploxyton</i> type (f) which, due to damages, covering debris or unfortunate positions, could not be identified separately.
Plantaginaceae undiff	All grains which show close morphological resemblance with most pollen types produced by Plantaginaceae taxa (cf. Punt & Clarke 1980) which were not - or could not be - further identified. The characteristics were not systematically noted to allow for univocally morphological descriptions.
<i>Potamogeton</i> type	All inaperturate reticulate grains without thick grain wall; includes <i>Callitriche</i> (m), <i>Potamogeton</i> subgenus <i>Coleogeton</i> type (m), <i>Potamogeton</i> subgenus <i>Potamogeton</i> type (m), and possibly other reticulate grains from which, due to damages and/or folds, no aperture could be seen and/or wall grain thickness could not accurately be estimated.
Rugulate <i>Spyrogyra</i>	Morphological entity closely resembling <i>Spyrogyra</i> spores, e.g. Types 130, 131 and 132 of Pals et al. (1980), but with a different, rugulate wall structure.
<i>Sparganium emersum</i> excl. <i>Typha ang.</i>	The <i>Sparganium emersum</i> type of Punt (1976) with a clear regular, not labyrinth-like reticulum, thus effectively excluding <i>Typha angustifolia</i> grains.
Striate Rosaceae undiff.	All striate grains with operculate endopori which were not - or could not be - further identified.
Tertiary trilete spores	All trilete spores which could not be identified with the aid of the available keys and were therefore interpreted as redeposited Tertiary spores.

Table 1. Continued

Name	Description
Tertiary type 1	Pollen type closely resembling Tertiary type 3, but with convex walls.
Tertiary type 2	Pollen type closely resembling Tertiary type 3, but with concave walls.
Tertiary type 3	Pollen type which could not be identified with the aid of available quaternary pollen identification keys and was therefore assumed to be a redeposited pollen type from the Tertiary. It closely resembles a pollen type presented by Fries and Ross (1950, Plate I, Fig. 6).
Trilete spores undiff.	Trilete spores which could not be identified with the available identification literature, of which morphological characteristics were not noted.
Zygnemataceae undiff.	Spores similar to Type 314 and the complex of Type 313 of van Geel et al. (1981) which were not further identified.

(sg) and tetrads were counted separately. Non-pollen palynomorphs (g) were identified after van Geel (1978) and Pals et al. (1980).

Calculation and presentation of the palynological data (Figs 4, 5), is with aid of the computer programs TILIA 1.12, TILIA GRAPH 1.18, and TGView 1.6.2 (Grimm 1992, 2004). Pollen percentage values in Figure 4 are calculated relative to a pollen sum including only types that, within the Lateglacial landscape, can be attributed to trees and shrubs (AP) and herbs (NAP) growing outside the studied basin. Pollen types that might also originate from wetland herbs (e.g. wild grass group and Cyperaceae) are excluded from the pollen sum in Figure 4 since they might falsely indicate an open regional vegetation if that pollen stems from a wetland vegetation within the basin (Janssen & IJzermans-Lutgerhorst 1973, De Klerk 2004a). In order to allow for a direct comparison with other pollen diagrams covering the Lateglacial calculated relative to an „Iversen pollen sum” (cf. De Klerk 2004a) that also includes pollen attributable to possible lake-shore and mire plants, Figure 5 presents a selection of the most important types relative to an Iversen sum. Pollen types assumed to be of exotic origin – i.e. representing erosional redeposition (Iversen 1936) or extra-regional pollen deposition (*sensu* Janssen 1973) – are also excluded from the pollen sum in both Figures 4 and 5. The pollen types *Pinus haploxylo-* type and *Alnus* are not considered as necessarily exotic, since some species that produce these types might have grown in the Lateglacial landscape of NE Germany (e.g. *Pinus cembra* or *Alnus viridis*). An unknown portion of the other grains is probably also of exotic origin.

The pollen frequencies in the pollen diagram (Figs 4, 5) are displayed with percentage values (closed curves) and a 5-times exaggeration (open curves with depth bars). The sum histograms present the absolute figure of the pollen sum. The pollen diagram is divided into

Site Pollen Zones (SPZ's, cf. De Klerk 2002). We do not apply the frequently used term Local Pollen Assemblage Zone (LPAZ). First of all, this term might erroneously suggest that such zones are based on types displaying local pollen values (*sensu* Janssen 1973) whereas normally such zones are based on types with regional pollen values. Secondly, such zones are normally acme zones or interval zones according to the International stratigraphic guide (Hedberg 1976, Salvador 1994) and are not conform to the definition of assemblage zones in this guide.

Frequencies of pollen types not displayed in the pollen diagram are listed on Table 2.

MACROFOSSIL ANALYSIS

Macrofossil samples of some selected levels (Tab. 3) were washed with water and sieved (meshes 1.0 and 0.50 mm). Since the aim was to find AMS-datable macrofossils, it was not attempted to retrieve the smallest macrofossils that would hardly have provided the necessary mass. Macrofossils were analysed only qualitatively and identified after Katz & Katz (1933), Körber-Grohne (1964), Grosse-Brauckmann (1972), Birks (1980), Frahm & Frey (1992), and Grosse-Brauckmann & Streitz (1992).

DIATOM ANALYSIS

Samples for diatom analysis were dried at 550°C, boiled in 10% HCl and in 10% H₂O₂, and mounted in Canada balsam. Counting was with a light-microscope with magnifications up to 1200-times. Identification, nomenclature and palaeoecological interpretation follow Krammer & Lange-Bertalot (1986, 1988, 1991a, b) and Krammer (1992). The results of the diatom analyses are shown in Figure 6 that presents observations of few taxa (+: 1–2 specimens; ++: 2–5 specimens; +++: 6 or more specimens) or relative values (closed curves: actual percentage values of total observed specimens; open

Table 2. Frequencies of pollen types not displayed in the pollen diagram (pollen type; sample in cm, depth; percentage)**Pollen type:** Sample in cm depth; (percentage)**AP:** *Betula pubescens* type (p) clumps: 145(0.3) *Betula/Corylus* (*): 278(0.5) cf. *Hippophaë rhamnoides* (m): 291(0.5) 265(0.3)262(0.3) 222(0.2) 206(0.2) cf. *Juniperus* type (*) clumps: 276(0.8) *Pinus diploxylon* type (f) clumps: 275(0.5)**NAP:** *Aethusa cynapium* type (p): 255(0.3) *Armeria maritima* type A/ *Limonium vulgare* type A (m): 278(0.5) 274(0.6) 226(0.3) *Anagallis arvensis* type (p): 155(0.2) *Anthriscus sylvestris* type (p): 291(0.5) 240(0.3) 193(0.7) 192(0.3) 189(0.2) *Arbutus unedo* (m): 232(0.3) *Arctostaphylos uva-ursi* (m): 165(0.3) *Arenaria montana* (p): 165(0.3) 135(0.3) cf. *Artemisia* (m): 292(0.5) 246(0.3) 125(0.3) *Astragalus alpinus* (m): 275(1.4) 268(0.6) *Astragalus danicus* type (m): 269(0.7) 262(0.3) 234(0.3) 220(0.2) 184(0.2) *Avena-Triticum* group (m): 130(0.3) *Botrychium lunaria* type (m): 283(0.5) 267(0.4) 242(0.3) 145(0.3) *Bupleurum falcatum* group (p): 234(0.3) cf. *Buxus* (m): 274(0.6) *Carum carvi* type (p): 204(0.5) 192(0.3) *Centaurea cyanus* type (m): 259(0.4) 120(0.6) *Cerealia* undiff. (*): 90(0.3) *Circaea* (m): 208(0.2) cf. *Cornus mas* type (p): 224(0.3) *Crithmum maritimum* type (p): 262(0.3) *Dianthus superbus* type (p): 214(0.2) cf. *Digitalis purpurea* type (m): 276(0.8) *Diphasiastrum* type (m): 271(0.6) *Ephedra distachya* type (m): 282(0.5) *Ephedra fragilis* type (m): 282(0.5) 216(0.2) *Falcaria vulgaris* type (p): 145(0.3) cf. *Fumana* type (m): 291(0.5) *Glaucium flavum* type (p): 255(0.3) *Heracleum sphondylium* type (p): 269(0.7) cf. *Heracleum sphondylium* type (p): 295(0.3) *Jasione* type (m): 184(0.2) 175(0.2) *Levisticum officinale* type (p): 200(0.2) *Lonicera periclymenum* type (p): 277(0.5) *Lycopodium annotinum* type (m): 263(0.5) 262(0.3) 261(0.4) *Lycopodium clavatum* type (p): 230(0.3) *Onobrychis* type (m): 240(0.3) 236(0.3) cf. *Onobrychis* type (m): 267(0.4) *Ononis* type (m): 266(0.3) 264(0.4) 260(0.4) 150(0.2) *Pimpinella anisum* type (p): 224(0.3) *Pimpinella major* type (p): 232(0.3) 212(0.2) 130(0.3) 120(0.3) *Plantaginaceae* undiff. (*): 293(2.7) 289(1.1) 288(0.7) 286(1.0) 282(0.5) 105(0.3) 278(0.5) 265(0.6) 258(0.3) 250(0.3) 218(0.4) *Plantago coronopus* type (p): 278(0.5) 265(0.6) 258(0.3) 250(0.3) 218(0.4) *Plantago lanceolata* type (p): 270(0.5) *Plantago major/media* type (p): 260(0.7) 208(0.2) *Plantago maritima* type (p): 288(0.7) 276(0.8) 256(0.4) 236(0.3) 214(0.2) 208(0.2) 200(0.2) 135(0.3) cf. *Plantago maritima* type (p): 281(0.6) *Plantago tenuiflora* type (p): 230(0.3) *Polygonum aviculare* type (p): 283(1.1) 258(0.3) *Polypodium vulgare* type (m): 255(0.3) 244(0.2) 224(0.3) cf. *Polypodium vulgare* type (m): 222(0.2) cf. *Polystichum* type (m): 224(0.3) *Pteridium aquilinum* type (m): 261(0.4) 234(0.3) *Sanguisorba minor* (f): 277(0.5) 259(0.4) 254(0.5) 253(0.6) 244(0.2) 226(0.3) 224(0.3) cf. *Sanguisorba minor* (f): 293(0.7) 282(0.5) 277(0.2) 255(0.3) 251(0.7) 246(0.6) 238(0.3) 234(0.3) cf. *Seseli libanotis* type (p): 277(0.5) *Silene dioica* type (p): 206(0.2) 155(0.2) 130(0.3) *Sison amomum* type (p): 264(0.4) *Trinia glauca* type (p): 218(0.4) 175(0.2) *Urtica dioica* type (p): 292(0.5) 274(0.6) 251(0.3) 232(0.3) 230(0.3) 160(0.3) 155(0.3) 120(0.3)**ASSUMED EXOTIC TYPES:** *Abies* (m): 284(0.5) 278(0.5) 269(0.7) 268(0.6) *Acer campestre* type (p): 273(0.7) 264(0.4) 256(0.4) 244(0.2) 160(0.3) cf. *Acer campestre* type (p): 283(0.3) 228(0.3) *Betuloid* type (*): 292(0.5) 291(0.5) 281(0.6) 278(1.5) 277(0.5) 261(0.4) 258(0.3) 257(0.5) 250(0.3) 246(0.6) 230(0.3) 248(0.3) 226(0.6) 155(0.2) 140(0.3) *Bisaccate* undiff. (*): 224(0.3) 95(0.2) cf. *Carya cordiformis* type (p): 261(0.4) 222(0.5) 115(0.4) *Cedrus* (f): 208(0.2) *Coryloid* type (*) clumps: 278(0.5) cf. *Fagus sylvatica* type (p): 292(0.5) 278(0.5) 234(0.3) 130(0.3) 90(0.3) *Frangula alnus* (m): 262(0.3) cf. *Ilex* type (m): 224(0.3) *Juglans regia* type (p): 274(0.6) cf. *Liquidambar styraciflua* (m): 246(0.3) *Myrica* (m): 196(0.2) *Nyssa* (m): 275(0.5) 252(0.7) 242(0.3) 222(0.2) 182(0.3) 115(0.4) cf. *Nyssa* (m): 259(0.4) 258(0.3) 248(0.7) 222(0.2) 105(0.3) *Pterocarya fraxinifolia* type (p): 264(0.4) 263(0.5) 258(0.3) 256(0.4) 254(0.5) 253(0.3) 228(0.3) cf. *Pterocarya fraxinifolia* type (p): 257(0.2) 234(0.3) 230(0.3) 226(0.6) 175(0.2) cf. *Rhus typhina* (m): 290(1.4) 279(0.5) 278(1.0) 253(0.3) 234(0.3) *Ribes rubrum* type (m): 254(0.5) 224(0.3) cf. *Ribes rubrum* type (m): 271(1.2) cf. *Sambucus nigra* type (p): 253(0.3) *Sorbus* (f): 244(0.2) *Tertiary type 2* (*): 270(0.5) 246(0.3) *Viscum* (m): 276(0.8) cf. *Viscum* (m): 280(0.6)**POLLEN TYPES EXCLUDED FROM THE SUM:** *Anagallis tenella/minima* (p): 271(0.6) *Angelica palustris* type (p): 188(0.2) *Anthemis* type (m) clumps: 274(1.7) cf. *Apiaceae* undiff. (*): 251(0.3) *Apium inundatum* type (p): 218(0.4) 182(0.6) *Caltha palustris* type (p): 260(0.4) cf. *Caltha palustris* type (p): 271(0.6) *Carum verticillatum* type (p): 253(0.3) *Chaerophyllum bulbosum* type (p): 264(0.4) cf. *Chaerophyllum hirsutum* (p): 110(0.4) *Chaerophyllum temulentum* type (p): 175(0.2) *Chamaenerion angustifolium* type (m): 204(0.5) 202(0.3) 192(0.2) 160(0.3) 155(0.5) *Cicuta virosa* type (p): 296(0.4) 238(0.3) 236(0.3) 208(0.2) 200(0.7) 182(0.3) 145(0.3) 125(0.3) *Cirsium/Serratula* type (m): 264(0.4) 216(0.2) 213(0.3) 212(0.2) 200(0.2) 175(0.2) 170(0.5) 150(0.2) cf. *Dryopteris filix-mas/D. cristata* type (m): 236(0.3) cf. *Euphorbia* (m): 276(0.8) 234(0.3) cf. *Fabaceae* undiff. (*): 293(0.7) 287(0.8) 284(0.9) 282(0.5) 279(0.5) 267(0.4) 265(1.6) 248(1.4) cf. *Filipendula* (m): 286(2.2) 281(0.6) 259(0.4) 253(0.3) 238(0.3) 120(0.3) *Geum* (m): 230(0.3) 228(0.3) 191(0.5) *Hornungia* type (m): 262(0.3) cf. *Hornungia* type (m): 281(0.6) cf. *Lotus* type (m): 270(0.5) 260(0.4) *Melampyrum* type (m): 277(0.5) *Mentha* type (m): 259(0.4) 120(0.3) cf. *Mentha* type (m): 263(0.5) 238(0.3) cf. *Menyanthes trifoliata* type (p): 281(0.6) 267(0.4) 238(0.5) 90(0.3) *Moehringia trinervia* group (p): 110(0.4) *Myriophyllum verticillatum* type (p): 95(0.2) 90(0.3) *Narthecium/Fritillaria/Scilla* type (m): 165(0.3) cf. *Nymphaea alba* type (p): 265(0.3) 246(0.3) *Oenanthe fistulosa* type (p): 276(0.8) 202(0.3) 196(0.2) 160(1.7) 145(0.3) 115(0.4) *Parnassia palustris* type (m): 272(1.3) 262(0.3) 244(0.2) 228(0.3) *Peucedanum palustre* type (p): 261(0.4) 191(0.2) 165(0.3) 105(0.6) *Pinguicula* (m): 175(0.2) *Polemonium* (m): 240(0.3) cf. *Potentilla* type (m): 252(0.7) 244(0.7) 145(1.4) 140(0.8) cf. *Ranunculus acris* type (p): 283(0.5) 100(0.5) *Rumex acetosa* group (p): 265(0.3) 254(1.0) 252(0.4) 220(0.2) 214(0.2) 170(0.2) *Rumex acetosa* type (p): 287(0.8) 262(0.3) 200(0.2) 165(0.3) 160(0.3) *Rumex conglomeratus* group (p): 240(0.3) *Sagina apetella* group (p): 255(0.3) *Sagina procumbens* type (p): 200(0.2) cf. *Saxifraga oppositifolia* type (p): 272(0.7) *Saxifraga stellaris* type (p): 230(0.3) 226(0.3) 175(0.5) cf. *Saxifraga stellaris* type (p): 277(0.5) 262(0.3) 234(0.7) 224(0.3) cf. *Scrophularia* type (m): 260(0.4) cf. *Scutellaria* type (m): 278(1.0) cf. *Sedum* type (m): 274(0.6) 232(0.3) 224(0.3) cf. *Selaginella selaginoides* (m) sg.: 226(0.3) *Selaginella selaginoides* (m) tetrads: 250(0.6) 224(0.3) *Silaum silaus* type (p): 204(0.5) cf. *Sinapis* type (m): 267(0.4) 259(0.4) 238(0.3) 232(0.3) 216(0.7) *Sium latifolium* type (p): 256(0.4) 255(0.3) 240(0.3) *Solanum dulcamare* type (p): 150(0.2) cf. *Solanum dulcamare* type (p): 269(0.7) *Sparganium emersum* type (p): 293(0.7) 261(0.4) 155(0.2) *Sparganium erectum* type (p): 282(0.5) 261(0.4) 258(0.3) 257(0.2) 242(0.3) *Striate Rosaceae* undiff. (*): 278(0.5) 258(0.3) 255(0.3) 226(0.3) 190(0.3) 100(0.3) cf. *Trifolium* type (m): 269(0.7) *Typha angustifolia* (p): 290(0.7) 270(0.5) 226(0.3) 200(0.2) 194(0.2) *Utricularia* (m): 192(0.3) 90(0.3) cf. *Valeriana dioica* type (p): 214(0.2)**NON-POLLEN PALYNOMORPHS:** *Amphitrema flavum* (Type 31) (g): 268(0.6) *Entophlyctis lobata* (Type 13) (g): 175(0.2) *Fern sporangia* (*): 292(0.5) 244(0.2) *Mougeotia* (Type 133-136) (g): 260(0.4) 248(0.4) 212(0.2) 194(0.2) 190(0.5) 182(0.3) 170(0.2) 95(1.1) *Neurospora* (Type 55C) (g): 232(0.3) 198(0.2) *Reticulate Spyrogyra* (Type 132) (g): 220(0.2) 214(0.2) 182(0.3) 175(0.2) *Rugulate Spyrogyra* (*): 281(0.6) 277(1.1) 265(0.3) 257(0.2) Type 8E (g): 226(0.3) 213(0.3) 145(0.3) *Zygnemataceae* undiff. (*): 191(0.2)**INDET:** Indet. clumps: 278(0.5) 274(0.6) 251(0.7)

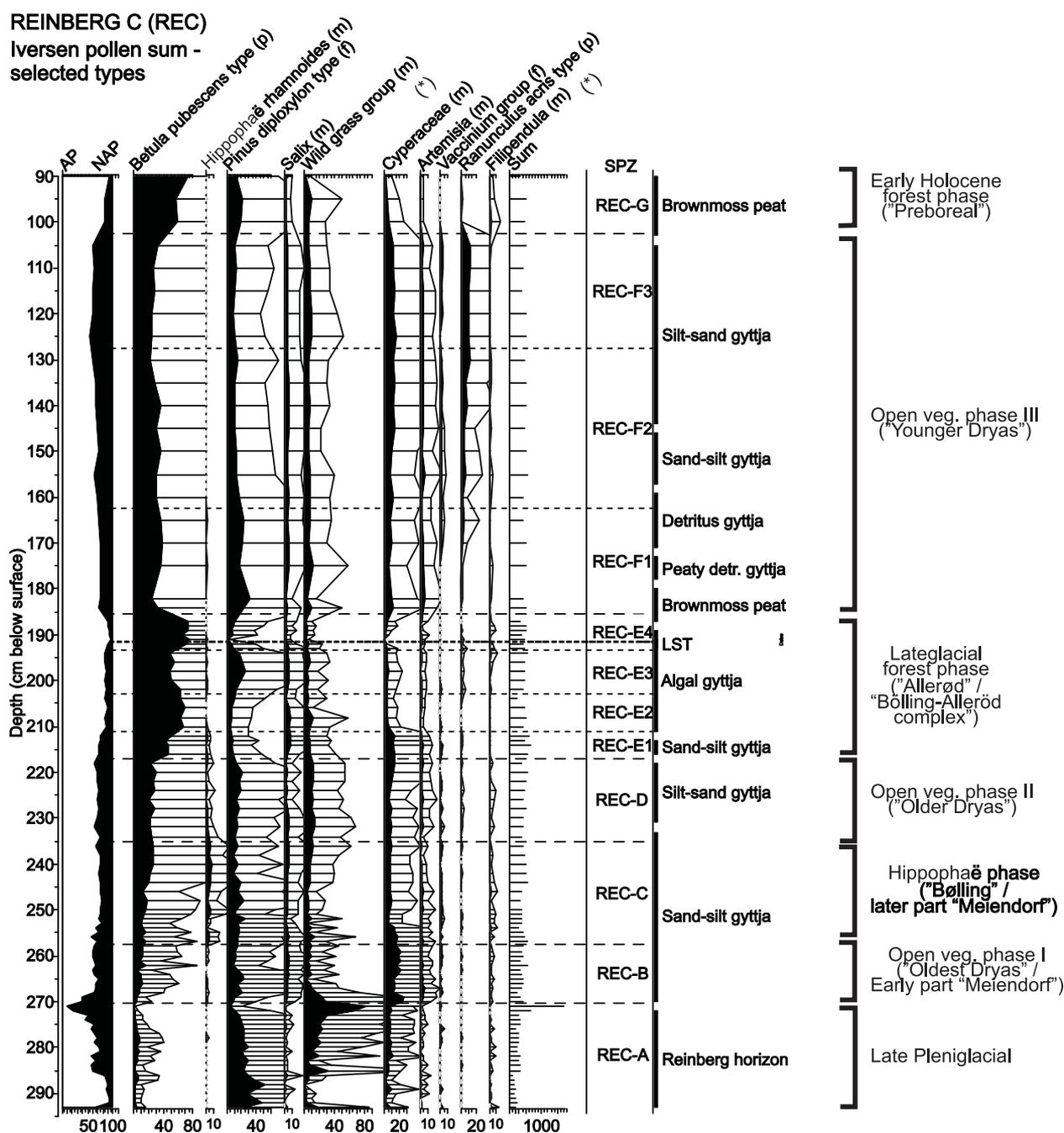


Fig. 5. Pollen percentage diagram "Reinberg C", calculated relative to an "Iversen" pollen sum

Table 3. Macrofossils of selected levels of core Reinberg C

Depth range (cm)	Macrofossils
104–101	<i>Betula pubescens</i> nuts, leaves and bud/fruit scales; fragments of <i>Pinus</i> seeds; <i>Carex</i> nuts; <i>Nymphaea</i> seeds; <i>Potamogeton</i> leaf fragments; leaves of the "wet variety" of <i>Drepanocladus</i>
186–180	moss remains (mainly <i>Calliergon giganteum</i>)
218–216	<i>Chara</i> -oospores; stem fragments; charcoal particles; waterflea eggs
236–234	wood fragments; charcoal particles
259–256	<i>Potamogeton</i> leaves; remains of <i>Chara</i> and/or <i>Nitella</i> ; moss fragments (a.o. <i>Drepanocladus</i>); insect fragments; few charcoal particles
293–271	<i>Juncus</i> seeds; cf. <i>Batrachium</i> fruits; Poaceae fruits; indeterminable seeds; indeterminable calyx; tissue fragments; root fragments; wood fragments; charcoal particles

curves: 5-times exaggeration). The sponge needles include needles of *Spongilla lacustris* and/or *S. fragilis*, and less prominent *Trochospongilla horrida* type. These were not counted separately because insufficient diatoms were found that could provide a reliable calculation basis (number of sponge needles per 100 diatoms). The column “Humine acid discolouring” displays the amount of silicate grains and diatoms that have been discoloured by dissolved humine acids. The column “black spots” indicates the observation of black spots among the clastic material, which are connected to humus formation. In order to allow an interpretation in terms of vegetation phases, the pollen zones of Figure 4 are incorporated in the diatom diagram.

SEDIMENT DESCRIPTION AND ANALYSIS

Field characterization of the sediments (Fig. 3) is after AG Boden (2005) using approximate English equivalents. Under gyttja, also sediments with less than 5% organic content were included since it is impossible to differentiate in the field between sediments with more and with less than 5% organic content (cf. Succow 1988). In core REC, a differentiation was made between sand-silt gyttja (containing more silt than sand) and silt-sand gyttja (containing more sand than silt).

Grain size frequencies (Fig. 7) were determined with the „Analysette A22” apparatus (cf. Fritsch GmbH 1994). Mean, standard deviation, and skewness of the grain size frequencies were calculated after Marsal (1979).

Total carbon content and inorganic carbon content were determined with the Eltra

metalyt CS 500 apparatus (cf. Birkelbach & Ohls 1995). CaCO₃ content was calculated by multiplying the inorganic carbon content with 8.33 (recalculated after Blume et al. 2000). Loss-on-ignition was determined by heating air-dry samples at 105°C for one hour and subsequent glowing at 550 °C. Furthermore, bulk density, dry weight, and weight per fresh volume were determined or calculated.

Sedimentation and accumulation rates are based on the calendar year chronology as discussed below (Tab. 4). Netto sedimentation rates (Tab. 5) are expressed as sediment thickness (mm) per year. Accumulation rates (presented in kg dry weight cm⁻² a⁻¹) were subsequently calculated as sedimentation rate * dry weight per wet volume (cf. Dearing 1986), allowing to express accumulation rates independent of water content.

In order to allow an interpretation in terms of vegetation phases, the pollen zones of Figure 4 are incorporated in Figure 7.

GEOCHRONOLOGY

The data is interpreted in terms of the “vegetation phases of Vorpommern” (De Klerk 2002, 2008) that were introduced to avoid a widespread confusion in stratigraphic and geochronologic terminology of the Weichselian Lateglacial (e.g. Usinger 1985, 1998, Hoek 1997, Björck et al. 1998, Kaiser et al. 1999, Litt & Stebich 1999, Eriksen 2002, De Klerk 2004a, Terberger et al. 2004). The plant names in these geochronological vegetation phases are not in *italics*, to conform to the general stratigraphic practice (cf. the plant name *Dryas* in the geochronological

Table 4. Tentative duration in radiocarbon years and calendar years of the vegetation phases of Vorpommern, after De Klerk (2002, 2008)

SPZ	Vegetation phases of Vorpommern	Tentative range in ¹⁴ C years B.P.	Tentative range in calendar years B.P.
REC-G	Early Holocene <i>Betula/Pinus</i> forest phase	<10 000-?	<11 600-?
REC-F3	Open vegetation phase III	11 000- >10 000	12 700->11 600
REC-F2			
REC-F1			
REC-E4	Lateglacial <i>Betula/(Pinus)</i> forest phase	11 800-11 000	13 650-12 700
REC-E3			
REC-E2			
REC-E1	11 900-11 800	13 750-13 650	
REC-D	Open vegetation phase II	12 000-11900	13 800-13 750
REC-C	<i>Hippophaë</i> phase	12 450-12 000	14 450-13 800
REC-B	Open vegetation phase I	12 900-12 450	15 350-14 450
REC-A	Late Pleniglacial	? - 12 900	? - 15 350

Table 5. Tentative sediment accumulation rates of core Reinberg C. For information on calculation: see text

Vegetation phases of Vorpommern	Tentative calendar age ranges	Tentative duration (cal yr)	Sediment thickness (mm)	Netto sedimentation rate (mm/cal. yr.)	Dry weight/wet volume (g/cm ³)	Accumulation rate (kg/m ² /cal. yr.)
Open vegetation phase III	12 700–11 600	1100	830	0.75	0.74	0.55
Lateglacial <i>Betula/Pinus</i> forest phase	13 750–12 700	1050	315	0.3	0.37	0.11
Open vegetation phase II	13 800–13 750	50	180	3.6	1.36	4.9
<i>Hippophaë</i> phase	14 450–13 800	650	225	0.36	1.38	0.5
Open vegetation phase I	15 350–14 450	950	130	0.14	1.35	0.19

term Younger Dryas). For readers not familiar with these vegetation phases, additionally the more traditional terminology is provided, however with sufficient care due to a great variety of connected scientific problems (cf. De Klerk 2004a). For a complete overview of the correlation of the vegetation phases of Vorpommern with traditional stratigraphical and geochronological divisions of the Weichselian Lateglacial see De Klerk (2002, p. 297, 2004b, p. 32) and Terberger et al. (2004, p. 140).

It was not possible to obtain an independent radiocarbon chronology for core REC because AMS-dated samples showed a contamination from previous ¹⁴C-tracer experiments in the rooms where the samples were prepared (De Klerk et al. 2001). Since probably the complete core is contaminated, the dating of new samples would only have been possible by retrieving a new core and preparing a new pollen diagram, for which insufficient time and funds were available. The chronology used in the present study (Tab. 4), therefore, is the (partly hypothetical) radiocarbon year chronology of De Klerk (2002, 2008) based on own dates, and on a correlation with well-dated pollen diagrams from northern Vorpommern (Erdtmann 2002) and north-western Poland (Latałowa 1999).

A calibration of this radiocarbon chronology into calendar years was not performed because calibrations are still problematic, especially for the early Lateglacial (De Klerk 2004a, 2008, Reimer et al. 2004). Therefore, a calendar year chronology (Tab. 4) was based on a comparison with palynological studies of annually laminated sections from eastern Poland (Ralska-Jasiewiczowa et al. 1995, revised by Goslar et al. 1999), northwestern Germany (Merkt & Müller 1999), and the Eifel region in western Germany (Stebich 1999, Litt & Stebich 1999). The significance of the various dates is debated in the discussion below.

DEVELOPMENT OF VEGETATION AND ENVIRONMENT AROUND THE REINBERG BASIN DURING THE WEICHSELIAN LATE PLENIGLACIAL, LATEGLACIAL AND EARLY HOLOCENE

SOME REMARKS ON THE OBSERVED DIATOMS

In oligotrophic water, which will have filled the Reinberg basin during the Weichselian Lateglacial, dissolved SiO₂ is rare. This not only limits the expansion of diatoms, but also favours the dissolution of the SiO₂-shales of dead diatoms and thus hampers the preservation of fossil populations (Harwood 1999). Due to these processes, diatoms in core Reinberg C are extremely rare. In the previous interpretation of De Klerk et al. (2001) identification of small diatom-fragments and diatom communities was made at a detailed level which is not justified by the actual scarce observations.

LATE PLENIGLACIAL (SPZ REC-A)

The basin sands that cover the basal tills show locally more or less horizontally positioned laminae ranging from a few mm to several cm in thickness. These are characterized by an alternation of finer and coarser material. This indicates that the sand was deposited in water. Since the sand reaches up to 15.5 m a.s.l. and possibly even higher (Fig. 3), water tables during the late Pleniglacial must at least have reached these heights.

SPZ REC-A (Fig. 4) is characterized by high relative values of *Pinus haploxylon* type, *Pinus diploxylon* type, and *Pinus* undiff., and low relative values of almost all other types, although some peaks occur in *Cerastium fontanum* group, *Armeria maritima* type A, *Armeria maritima* type B, *Anthemis* type, Lactuceae, Wild grass group, and Cyperaceae. This zone corresponds to the Reinberg horizon.

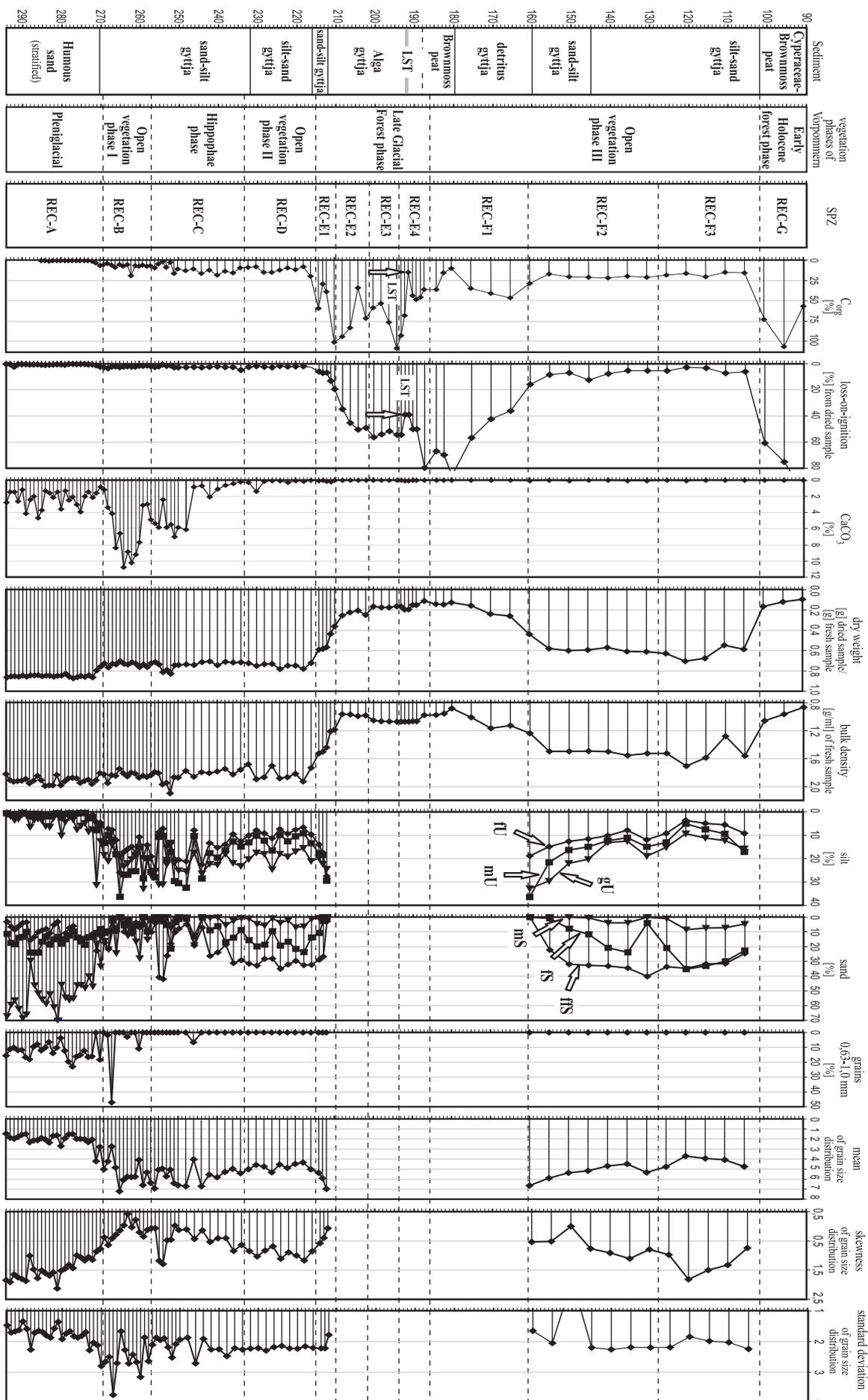


Fig. 7. Sediment parameters of core Reinberg C. Incorporated are the pollen zones of Fig. 4 and the corresponding vegetation phases. fU: grain size fraction 2.0–6.3 μm , mU: 6.3–20 μm , gU: 20–63 μm , fS: 63–125 μm , mS: 125–200 μm , fMS: 200–630 μm

Van der Hammen (1951, cf. van Geel et al. 1989, Hoek 1997) defined the beginning of the Lateglacial on a rise in *Artemisia* pollen that is considered to be synchronous over large distances. Since *Artemisia* pollen has only low values in SPZ REC-A, this zone is correlated with the late Pleniglacial.

Due to a high input of exotic pollen, it is extremely difficult to reconstruct the regional vegetation: single grains or low continuous values of pollen types do not provide any palaeoecological information due to their uncertain sources. Only clear peaks of (extra) local pollen deposition values (*sensu* Janssen 1973) indicate (extra) local presence of plant taxa. From such peaks, alternating presence around the core location of grasses, sedges, and producers of the *Cerastium fontanum* group, *Armeria maritima* type A, *Armeria maritima* type B, *Anthemis* type, and Lactuceae can be concluded. Macrofossils (Tab. 3) also prove presence of *Juncus*, *Batrachium* and Poaceae. Although the NAP curve calculated relative to an „Iversen pollen sum” (Fig. 5) indicates a gradual opening-up of the regional vegetation, this is only a mathematical bias of this pollen sum (including types with (extra)local values, e.g. attributable to Cyperaceae and Poaceae) and not an actual phenomenon.

A comparison of the pollen and macrofossil content of several short sections from the Reinberg horizon enabled De Klerk et al. (2001) to identify several other plant taxa in the middle sub-basin at the end of the Pleniglacial. They reconstructed an environment consisting of shallow wet ponds and low dry mineral mounds during a phase in which water levels were generally rather low. Water tables that previously were high, therefore, must have fallen considerably towards the end of the late Pleniglacial. The black spots observed in diatom samples 272 and 271 – interpreted to represent soil formation in a mainly dry environment – support this reconstruction.

The diatom spectrum in sample 288 indicates that shallow water within the middle sub-basin was dystrophic/oligotrophic with slight acid to neutral pH values and low electric conductivity (cf. the ecological requirements of the peaking taxa as given by Krammer and Lange-Bertalot 1986, 1988, 1991a, b).

OPEN VEGETATION PHASE I (SPZ REC-B) – OLDEST DRYAS OR EARLIER PART OF THE MEIENDORF

Zone REC-B (Fig. 4) shows higher relative values of *Artemisia* and *Betula pubescens* type and lower relative values of *Pinus diploxylon* type and *Pinus haploxylon* type pollen than in the underlying zone. Values of *Salix*, *Hippophaë rhamnoides* and *Juniperus* type/*Juniperus*-without-gemmae are also slightly higher.

The date of 15 350 calendar years B.P. for the beginning of the Lateglacial (Tab. 4) is unreliable, because no annually laminated sections reach down to this event, although Stebich (1999) and Litt and Stebich (1999) claim this for their data. However, they base their definition of the beginning of the Lateglacial not on a rise in *Artemisia* pollen values as is normally done in palynological studies (van der Hammen 1951, Iversen 1954, Menke 1968, van Geel et al. 1989, Hoek 1997, De Klerk 2008). On the contrary, the high values of *Artemisia* pollen at the base of the diagram of Stebich (1999) and Litt & Stebich (1999) suggest that this diagram does not cover the end of the Weichselian Pleniglacial, but starts in the early Lateglacial. Our estimation of 15 350 calendar years B.P. is the rounded mean of the outcome of various calibration programs (De Klerk unpublished data) and must be used considered with great care.

The transition from the Pleniglacial to the Lateglacial relates probably to a rise in temperature, of which the extent is still uncertain. Coleoptera data from several European localities suggest a rapid warming around 13 000/12 900 ¹⁴C years B.P. (e.g. Coope 1986, Atkinson et al. 1987, Bohncke et al. 1987, van Geel et al. 1989). Stable oxygen isotope data from the European mainland, however, indicate a major temperature rise somewhat later around 12 600/12 500/12 450 ¹⁴C years B.P. (cf. Lotter et al. 1992, Ammann et al. 1994, Hammarlund & Lemdahl 1994, Hoek et al. 1999). Oxygen isotope data from the Greenland ice cores date a major warming around 14 700 calendar years B.P. (Stuiver et al. 1995, Björck et al. 1998) that is generally correlated with the temperature rise of 12 900 ¹⁴C-years B.P. (cf. Björck et al. 1998, Lowe et al. 1999, Mayle et al. 1999). However, a date of 14 700 ice-core years B.P. corresponds to a radiocarbon age of ca. 12 400 ¹⁴C years B.P. (interpolated from data provided by Jöris & Weninger 1998, cf. De Klerk 2004a). The rise in temperature at

the beginning of Open vegetation phase I in the region of NE Germany that triggered the expansion of *Artemisia* species might only have been a minor temperature increase or an extension of duration of summer warm periods (cf. De Klerk 2008).

The sediment at the base of SPZ REC-B changes from sand to gyttja. This shows that – compared to the late Pleniglacial – water levels had risen. The relation between this water level rise and the rising temperatures is still unclear. A possible cause is a change in the water storage of the soils (e.g. groundwater levels had gradually risen above the basin floor).

Figure 4 and Table 2 show many pollen types attributable to open vegetation types such as *Artemisia*, *Helianthemum*, Ericales, Chenopodiaceae, *Dryas*, and members of the Plantaginaceae family. This indicates the presence of predominantly herbaceous vegetation types in the regional vegetation surrounding the Reinberg basin. The presence of *Salix*, *Juniperus*, and probably *Populus* is indicated by the relevant pollen types produced by these taxa. That nevertheless high AP pollen frequencies occur is mainly due to long-distance transport of *Pinus* pollen, which generally dominates pollen deposition in open landscapes due to good pollen dispersal of pine (cf. van Leeuwaarden & Janssen 1987). Although AP pollen values are lower calculated relative to an „Iversen pollen sum (Fig. 5), also here considerable values of pine pollen occur. It is possible that pine was incidentally present in the regional vegetation of northern Germany during the early Lateglacial (Usinger 1998). From a large peak of *Betula pubescens* type pollen in a short section of the Reinberg horizon, De Klerk et al. (2001) concluded that also incidental birch trees were present in the Reinberg area. Although this might have been the case (cf. Kullman 2002), the recent discovery that *Betula nana* shrubs in NE Siberia produce pollen of both the *Betula nana* type and the *Betula pubescens* type (De Klerk et al. in press) places some doubts to such an unambiguous inference. This example illustrates clearly, why a strict separation between observed pollen morphological types and inferred plant taxa is crucial in palynology since an unambiguous relation between pollen types and inferred plant taxa might be defective (Joosten & De Klerk 2002, De Klerk & Joosten 2007). *Hippophaë rhamnoides* pollen occurs almost continuously in SPZ REC-B with low values, showing that

also sea-buckthorn was regionally present. In general, the regional vegetation can be expected to have been rather sparse, but will have been denser than during the late Pleniglacial.

The sediment data (Fig. 7) show strong fluctuations in the 630–1000 µm grain size and the medium sand grain-size curves, indicating incidental input of coarse material. The strong fluctuations in both mediate grain size and standard deviation demonstrate that sedimentation was rather irregular. The skewness, however, indicates a gradual fining-upward tendency.

This observation – together with the reconstructed open regional vegetation – indicates the persistence of a dry continental climate with only little precipitation, due to which relatively fine-grained sediments were washed into the basin (compared to later vegetation phases): due to the open character of the regional vegetation, precipitation directly affected the soils, and erosion and subsequent sedimentation were consequently extremely irregular. The fining-upward tendency, however, points to a reduction of extreme erosion events and/or to an increasing protection by the vegetation towards the end of Open vegetation phase I.

Low amounts of *Botryococcus* and *Pediastrum boryanum* indicate that these algae inhabited the open water. *Botryococcus* had a short-lasting optimum at the beginning of Open vegetation phase I. The presence of *Potamogeton* and/or *Callitriche* can be inferred from the values of *Potamogeton* type.

The pollen diagram does not allow the reconstruction of a lake-shore vegetation. Silicate grains in the diatom samples that were discoloured by dissolved humine acids, however, are a strong indication that plants (producing the humine acid) were present in the basin. Substantial values of Cyperaceae pollen indicate that such lake-shore vegetation types may have included sedges, although from the values in Figures 4 and 5 it may also be possible that only pollen sources within the regional vegetation outside the basin are recorded. The low loss-on-ignition and C_{org} -values indicate low primary production (Fig. 7).

The $CaCO_3$ -content of the sediments increases sharply at the base of SPZ REC-B and demonstrates an increase of lime precipitation at the beginning of the Lateglacial. On the one hand, the increased temperatures will have stimulated an increased precipitation of $CaCO_3$ in the basin (Chrobok 1986). On the

other hand, two opposing processes worked in the dry soils surrounding the basin: increased biological activity as consequence of the slightly denser vegetation will have increased CaCO_3 -solution in the soils, but the higher temperatures will also have caused CaCO_3 -solution to decrease (Kuntze et al. 1994). The net effect of these opposite processes cannot be estimated. Since CaCO_3 -values in core REC have increased, the enlarged CaCO_3 precipitation in the basin due to the higher temperatures must have had the largest impact.

HIPPOPHAË PHASE (SPZ REC-C) – BØLLING OR LATER PART OF THE MEIENDORF)

SPZ REC-C is distinguished on its relative high values of *Hippophaë rhamnoides* pollen (Fig. 4).

Within the open regional vegetation *Hippophaë* shrubs expanded that - unhindered by shadowcasting trees - will have formed large dense stands (cf. De Klerk 2002, 2008). Since sea-buckthorn needs relatively high summer temperatures to flower (Kolstrup 1979, 1980), the increase in its pollen is probably the result of a further rise in summer temperatures. Increasing temperatures around 12 600–12 450 ^{14}C years B.P. have been demonstrated at many European localities. The rise of *Hippophaë rhamnoides* pollen values can be assumed to be synchronous over large distances since *Hippophaë* seeds are distributed by birds (Gillham 1970) and thus, sea-buckthorn most likely was present all over Europe since the beginning of the Lateglacial: a climatically-induced increase in values of *Hippophaë rhamnoides* pollen will have been synchronous over large distances. We use in Table 4 an age of 14 450 calendar years B.P., following the rise in *Hippophaë rhamnoides* in the diagram of Stebich (1999) and Litt & Stebich (1999) – although they originally erroneously dated this as the beginning of the Lateglacial.

It is unlikely that the expansion of sea-buckthorn needed a special threshold of soil development (cf. van Geel 1996), since it is able to grow on very poor soils (Pearson & Rogers 1962). In its ability to fix nitrogen (Pearson & Rogers 1962) it is an important plant for the production of nutrients and the consequent enrichment of the soils.

The relatively high NAP values in SPZ REC-C indicate that the vegetation remained predominantly open: minor peaks of the

relevant pollen types indicate an expansion of *Helianthemum* and *Salix* at the end of the Hippophaë phase. The gradual rise of *Betula pubescens* type values might indicate that also tree birches expanded slightly: most likely only incidental specimens were present, since otherwise *Hippophaë* would have been shaded-out. The incapability of *Betula* trees to form dense stands can be attributed to a dry continental climate that hindered the rather oceanic birch (cf. Usinger 1998), or to insufficiently developed soils (van Geel 1996).

The trend of gradually decreasing grain sizes continues (Fig. 7) and shows that soil erosion became gradually less severe. This is also demonstrated by a general decrease in values of assumed exotic pollen types. Sediment grains between 630 and 1000 μm do not occur above 245 cm depth. This reduced soil erosion will be related to a stabilising effect on soils of the extensive root system of *Hippophaë*, as well as protection of its dense canopy against splashing rain (Rousi 1965, Li Min et al. 1989, Li Quanzhong et al. 1989). The low AP+NAP concentrations, high values in the coarser grain-size fractions and the skewness of the grain size distribution, and a peak in assumed exotic types indicate an extreme erosion event registered between samples 255 and 252 (Figs 4, 7).

Between 242 and 236 cm, the hardly fluctuating standard deviations of the sediment parameters show a trend to a more regular sedimentation. Mean grain sizes and the skewness at the same level, however, show an increase of sandy material.

Pediastrum, *Botryococcus*, and *Potamogeton* and/or *Callitriche* species inhabited the water in the basin as is indicated in the pollen diagram (Fig. 4). Macrofossils at the base of SPZ REC-C (Tab. 3) confirm the presence of *Potamogeton* and show that also *Chara* or *Nitella* was present. No conclusions about a lake-shore vegetation can be drawn from the pollen record since pollen types produced by wetland plants occur with too low values to unambiguously infer local presence of their sources in the basin. However, the occurrence of humine acid discolouring of clastic particles in the diatom samples indicates again the presence of plants within the basin. *Cyclotella bodanica* (Fig. 6) indicates the presence of clear, oligotrophic water, although the scarce amount of observed diatoms does not allow major conclusions.

The CaCO₃-content decreases markedly between 248 and 247 cm (Fig. 7), and towards the end of the *Hippophaë* phase lime precipitation had completely ceased. This can hardly be related to a change in temperature, since that would also have been reflected in the pollen curves. Although the scarce diatoms provide not much information, the low electric conductivity indicated in sample 288 and in samples from higher positions suggests that the Reinberg basin was not fed by groundwater: the water feeding the basin, thus, came mainly from precipitation, surface runoff and interflow. It is plausible that decalcification of the surrounding slope soils had progressed to such depths during the *Hippophaë* phase that the interflow had become deprived of CaCO₃.

OPEN VEGETATION PHASE II (SPZ REC-D) – OLDER DRYAS

SPZ REC-D contains lower values of *Hippophaë rhamnoides* pollen than previously and higher values of NAP-types (especially *Artemisia*) and of *Betula nana* type (Fig. 4). Values of *Salix* and *Juniperus* type pollen decrease after an initial peak. The decrease of *Hippophaë* dates around 12 000 radiocarbon years B.P. in northern Germany and Poland (Latałowa 1999, De Klerk 2002), and at 13 800 calendar years B.P. in the records of Stebich (1999), Litt & Stebich (1999) and Merkt & Müller (1999). The date for the beginning of the subsequent vegetation phase (Tab. 4, cf. discussion below) gives Open vegetation phase II a duration of only 50 calendar years, which is extremely short. This might be due to the insecure age estimations presented here. More dates that are reliable are desirable in order to get more clarity.

Hippophaë must have lost importance in the regional vegetation, whereas dwarfshrubs (especially *Betula nana/humilis*, or *Betula* hybrids) and herbs (especially *Artemisia*) expanded. This shows that a vegetation regression had occurred. The only slightly decrease in *Betula pubescens* type values might indicate that tree birches remained an incidental vegetation element. The rather low relative values of *Juniperus* type and *Juniperus*-without-gemmae show that juniper did not greatly expand, which is in contrast with inference from the Endinger Bruch area in Vorpommern ca. 20 km west of the Reinberg basin (De Klerk 2002).

The vegetation regression most likely reflects a decrease of summer temperatures.

Such a temperature decrease at the same time period is also concluded from Coleoptera and oxygen isotope studies from other regions (Ammann et al. 1994, Walker et al. 1994, Björck et al. 1998). The hypothesis that Open vegetation phase II (in the denunciation as Earlier Dryas) was characterized by drought rather than cold (cf. Van Geel & Kolstrup 1978, Kolstrup 1982) is contradicted by the diminishing of *Hippophaë* which can withstand great drought (Pearson & Rogers 1962, Bat et al. 1988). The gradually increasing grain sizes in core REC during this and the previous vegetation phase even suggest that precipitation had gradually increased, allowing the coarser grain fractions to be washed into the basin.

Conspicuously, this vegetation phase is prominently registered in basins in northern Vorpommern, whereas it hardly can be traced in regions only few hundreds of km further to the south. This is attributable to somewhat higher temperatures in these southern regions and consequently more stable soils under a denser vegetation (cf. De Klerk 2002, 2008).

In the middle sub-basin of Reinberg, a relatively coarse silt-sand gyttja was deposited. Although assumed exotic pollen types still show a decreasing tendency, their values are prominently higher than at the top of the underlying pollen zone. Both sediment and assumed exotic types, hence, demonstrate a prominent increase in soil erosion during Open vegetation phase II. This is also reflected in the high accumulation rates (Tab. 5), even if the uncertainty of the dates are taken into consideration: if the duration of this vegetation phase is wrongly estimated with a factor 5 (which is unlikely high), accumulation rates are still a factor 2 higher than previously. Increased soil erosion was favoured by the higher precipitation and by the disappearance of the stabilising *Hippophaë* stands. The relatively stable curves of the grain sizes, their means, and their standard deviation point to more regular erosion and sedimentation patterns than during the preceding vegetation phases.

A small peak of *Pediastrum boryanum* at the base of SPZ REC-D points to a minor expansion of *Pediastrum* in the middle sub-basin. A continuous presence of *Potamogeton* and/or *Callitriche* is inferable from the pollen record. Macrofossils (Tab. 3) show that at the end of this vegetation phase *Chara* was present. No conclusions can be drawn about the lake-shore vegetation from

the pollen record, but the existence of such vegetation types are, again, indicated by the discolouring of the clastic particles in the diatom samples. The rare observed diatoms might indicate the presence of water with low to middle electric conductivity, although insufficient specimens occur to draw definite conclusions.

LATEGLACIAL BETULA/PINUS FOREST PHASE
(SPZ REC-E) – ALLERØD, OR BÖLLING-ALLERØD
COMPLEX SENSU USINGER (1985)

SPZ REC-E can be subdivided into four sub-zones implying four different sub-phases (Fig. 4).

The first sub-phase (SPZ REC-E1) is characterized by a gradual increase in *Betula pubescens* type values combined with relative high NAP-values. This shows a gradual expansion of birch trees in a still open regional vegetation. The pollen record shows that also *Salix* and *Juniperus* expanded slightly, and that *Hippophaë* remained present. Since tree birches were probably already present in both Vorpommern and western Germany (cf. Stebich 1999, De Klerk et al. 2001 and discussion above), a sudden expansion in relation to increasing temperatures and increased humidity was probably synchronous over large distances, although it might have occurred a little earlier in the warmer, more oceanic south-western part of Germany. As long as reliable dates from more near-by regions are lacking, the date of 13 750 calendar years of Stebich (1999) and Litt & Stebich (1999) is also used for Vorpommern. Several stable oxygen isotope curves indicate a presumably synchronous temperature rise (Ammann et al. 1994, Hoek et al. 1999). Maturing of the soils is another factor that might have influenced the expansion of birch trees (cf. van Geel 1996).

The sediments become finer-grained (sand-silt gyttja instead of silt-sand gyttja), which shows that soil erosion reduced as the consequence of the expanding forest. Increasing values of C_{org} and loss-on-ignition (Fig. 7) show that primary production within the middle sub-basin increased gradually, or that as result of the reduced input of clastic material it gained a larger relative importance.

Rising values of *Botryococcus* and *Pediastrum boryanum* show that the middle sub-basin became more favourable for *Pediastrum* and *Botryococcus*. Since the various taxa included in these morphological entities differ greatly in ecological requirements (cf.

Jankovska & Komarek 2000) it is unclear what the underlying environmental factors might have been. The higher frequency of humine acid discolouring in the diatom samples indicates an increased plant growth within the basin.

The second sub-phase (SPZ REC-E2) starts with a sharp decline in NAP-values, representing a rapid closing of the regional forests. The relative values of their pollen types show that *Juniperus* and *Hippophaë* populations diminished largely probably as result of the competition by birch trees, whereas *Salix* remained present. The estimation of 13 650 calendar years B.P. of the decrease in NAP pollen values (Tab.4) shortly above a rise in pollen ascribable to tree birches follows Merkt & Müller (1999).

Clastic sediments largely disappeared in the middle sub-basin: the dense forest vegetation surrounding the basin resulted in stabilisation of soils and prohibited erosion. The high C_{org} and loss-on-ignition values, as well as the sedimentation of pure algal gyttja, show a prominent primary organic production in the basin.

The middle sub-basin contained a wetland vegetation in which *Equisetum* was important, as can be concluded from the pollen diagram (Fig. 4). For the southern sub-basin, a vegetation type with prominent Cyperaceae was reconstructed (De Klerk et al. 2001). The abundance of *Pinnularia* remains (especially from *P. brevicostata*, *P. cardinalis*, *P. gibba*, *P. maior* and *P. nobilis*, Fig. 6) shows the presence of clear, oligotrophic lake water with low electric conductivity. Most *Pinnularia* species are living in and on aquatic sediments, but some of them might also tolerate temporal air exposure. These species might originate from habitats amidst the lake-shore vegetation.

The third sub-phase (SPZ REC-E3) shows prominent lower values of *Betula pubescens* type and higher values of *Pinus diploxylon* type. This will result from an expansion of pine in the Reinberg area, a decrease of the amount of birch trees (causing a mathematical increase in values of *Pinus diploxylon* type), or decreased flowering of tree birches related to the minor cooler phase known as „Gerzensee fluctuation” (De Klerk 2002, 2008). Since the third sub-phase is not (yet) independently dated in pollen diagrams from Vorpommern, this latter hypothesis can neither be confirmed nor denied. There is no corresponding sedimentary reaction inferable from the middle sub-basin, but a sandy layer in

the southern sub-basin probably corresponds to this third sub-phase (De Klerk et al. 2001).

Menyanthes and *Filipendula* invaded the *Equisetum* populations in the middle sub-basin, as rises in their pollen types indicate. Values of the relevant pollen types indicate also the presence of *Cicuta*, *Oenanthe*, and *Typha latifolia* in the basin: since assumed exotic types are largely absent, low amounts or single grains of other types can be interpreted to originate from the actual wetland vegetation, i.e. an exotic origin can be ruled out.

The diatom flora shows two different environments (Fig. 6). Remains from aquatic *Cymbella* species (probably predominantly *C. ehrenbergii* and *C. helvetica*) demonstrate an oligotrophic/mesotrophic water body with low to middle electric conductivity. Species that tolerate temporal air exposure (e.g. some of the *Pinnularia* taxa) show the presence of acid wet vegetation types that will have occurred in the basin shore vegetation types.

Increased values of *Betula pubescens* type pollen in SPZ REC-E4 prove that during the fourth sub-phase birch expanded again, or that *Betula* flowering increased. The regional vegetation will have resembled that of the second sub-phase. A short fluctuation occurs immediately above the Laacher See tephra (LST), where the pollen spectrum shows peaks of *Juniperus*-without-gemmae, *Juniperus* type and *Artemisia* pollen, whereas values of *Pinus diploxylon* type pollen decrease to almost zero. Similar fluctuations immediately above the Laacher See tephra occur in many other pollen diagrams from north-eastern Germany and indicate minor environmental changes immediately after the volcanic eruption (Theuerkauf 2003, De Klerk et al. 2008). The strong reduction in AP+NAP concentrations immediately above the tephra is the result of pollen-free tephra material in the analysed sample and does not necessarily indicate a reduction of regional pollen influxes. The presence of tephra material also explains the incidental lower values of loss-on-ignition and C_{org} in the relevant sample.

The diatom flora above the Laacher See tephra is rich and varied, and the *Pinnularia* species, *Navicula placentula*, *N. laevissima* and *N. tuscula*, *Neidium ampliatum* and *N. iris*, *Stauroneis anceps*, *Tabellaria flocculosa*, and others obtained a mass expansion combined with good preservation conditions. A similar

increase occurs also in other basins in Mecklenburg-Vorpommern (Theuerkauf 2003, De Klerk et al. in press) and results from an input of SiO_2 from the tephra that provided nutrition for the diatoms and prohibited solution of dead diatoms (Harper et al. 1986, Harwood 1999). This latter effect also explains the higher and more varied diatom content in the sample below the tephra. It is also possible that the change in sediment from gyttja to more porous tephra provided a more favourable habitat for some epipellic and epilithic taxa (De Klerk et al. in press). The increased amount of *Eunotia* species above the tephra indicates that the deposition of the tephra caused a (slight) acidification of the environment. These conclusions are supported by diatom analyses around the Laacher See Tephra in one of the other Reinberg sub-basins (De Klerk et al. 2008).

The pollen record suggests that the wetland vegetation in the middle sub-basin during the fourth sub-phase included *Equisetum*, *Menyanthes*, and *Filipendula*. *Botryococcus* and *Pediastrum* inhabited open water. At the end of the sub-phase, formation of brownmoss peat started (with dominance of *Calliergon giganteum*, Tab. 3). Contrary to *Pediastrum*, *Botryococcus* remained present. Spots of open water were inhabited by *Nuphar* as is shown by a peak of *Nuphar lutea* type pollen (Fig. 4). The presence of locally drier environments is indicated by high values of some *Pinnularia* species (Fig. 6). The diatoms further show the presence of oligotrophic acid water with low to middle electric conductivity.

The beginning of peat formation does not correspond in time with relevant changes in the regional vegetation and, therefore, cannot be considered to result from climatic change: it, hence, relates to basin-internal hydrological and/or vegetation dynamics. Possibly a floating vegetation mat had developed on top of the water surface.

OPEN VEGETATION PHASE III (SPZ REC-F) – YOUNGER DRYAS

SPZ REC-F contains prominently higher NAP values than the previous zone (cf. Fig. 4). Three sub-zones are distinguished that are based on further rises in NAP-types. The dates of ca. 12 700 calendar years B.P. for the beginning, and of ca. 11 600 calendar years B.P. for the termination of Open vegetation phase III are based on the correlation with the varve-

dated pollen diagrams of Goslar et al. (1999), Stebich (1999) and Litt & Stebich (1999), and Merkt & Müller (1999). The relevant vegetation changes (that are the result of climatic change) are likely to be synchronous over large distances and, thus, will date simultaneously. Since the different sub-phases in the Reinberg diagram are not dated, only a mean accumulation rate for Open vegetation phase III in total could be calculated (Tab. 5). This accumulation rate did probably not remain constant in the different sediment layers, which is indicated in fluctuations of the AP+NAP concentration curve, although these may also result from changes in pollen influxes or pollen preservation. The date of the upper boundary of SPZ REC-F is, furthermore, uncertain due to a hiatus (discussed below). The actual mean accumulation rate, thus, was most likely higher than the value given in Table 5.

The higher AP+NAP concentrations compared to the Open vegetation phase I and the *Hippophaë* phase show that the regional vegetation during Open vegetation phase III was denser and, hence, resulted in higher pollen influxes. Since sediment accumulation rates are higher or similar to those of the phases in the early part of the Lateglacial (cf. Tab. 5), a smaller accumulation rate can be ruled out as cause for these higher concentrations. These observations are in good accordance with a study of the Endinger Bruch area ca. 20 km to the west of Reinberg (De Klerk 2002).

The sudden increase of NAP values at the base of SPZ REC-F1 show that the first sub-phase started with a rapid opening of the regional vegetation. An open vegetation including *Artemisia*, *Betula nana/humilis*, *Salix*, and *Juniperus* expanded, as is indicated by higher values of the relevant pollen types. *Betula* and possibly *Pinus* trees were probably also present, but did not form closed stands (cf. De Klerk 2008).

The wetland vegetation reacted less rapidly on the climatic change at the beginning of Open vegetation phase III. At the beginning of the first sub-phase, the floating vegetation mat remained present in the basin, as is indicated by the peat at the base of SPZ REC-F1. However, soon this mat was drowned and a new aquatic environment developed in which (as the pollen record indicates) *Nuphar*, *Pediastrum* and *Botryococcus* were present. Relative high values of *Equisetum* spores show that along the basin shores *Equisetum* remained present.

The number of observed diatoms decreases conspicuously at the transition from peat to gyttja. The observed genera *Cymbella*, *Fragilaria*, and *Neidum* require oligotrophic/mesotrophic open water with low to middle electrolyte content and acid pH. Part of the *Eunotia* and *Pinnularia* species, however, tolerate temporal air exposure and might have occurred in the wetland vegetation along the basin shores (i.e. the *Equisetum* marshes).

The gradually decreasing loss-on-ignition values show that decreasing organic production or increasing sedimentation of eroded soil material occurred only slowly. The gradual change from peat along peaty detritus gyttja to finally detritus gyttja shows that water levels rose only gradually. Evapotranspiration will have decreased due to the disappearance of forests, and a consequently enlarged surface runoff caused lake levels to rise. Also seasonally frozen soils prevented precipitation to infiltrate and, after thawing during the probable short summer seasons, a sudden large water supply into the basin contributed to higher water levels.

The rise in NAP-values at the base of sub-zone REC-F2, mainly attributable to a rise in values of *Empetrum nigrum*, indicates a further opening of the regional vegetation in the second sub-phase. However, such a sudden opening is not visible in the diagram calculated with an „Iversen pollen sum” due to gradual rising values of Cyperaceae pollen values that do not necessarily originate solely from the regional vegetation but might also indicate a gradually expansion of marsh habitats along the basin shore. This is another illustration that interpretation of diagrams calculated relative to an „Iversen pollen sum” cannot be unambiguously interpreted (cf. De Klerk 2004a). During the second sub-phase, Ericaceous heath lands were a prominent regional vegetation element, in contrast to the regions of southern Mecklenburg, northern Brandenburg, and the Berlin area where open pine parklands formed a prominent vegetation type (Brandt 1995, De Klerk 2008).

The opening of the regional vegetation resulted in an increase of soil erosion, due to which clastic sediments were now deposited (cf. Figs. 4 and 7). The sediment change was shortly delayed, possibly because the threshold of vegetation to open-up was reached earlier than the threshold for enlarged soil erosion.

The higher organic content (compared to Open vegetation phases I and II, and the *Hippophaë* phase) shows that soil erosion during Open vegetation phase III was less severe because of the denser regional vegetation, or that organic production within the basin was higher. It is also imaginable that the material washed into the basin contained generally more organic material due to the gradual maturing of the soils during the previous vegetation phases. The lower relative values of assumed exotic types compared to the early Lateglacial are either the result of the less severe soil erosion, or due to a higher influx of contemporary regional pollen (i.e. the ratio between assumed exotic types and pollen sum types had changed in favour of the latter).

The *Equisetum* populations in the middle sub-basin seem to have lost importance and were possibly replaced by ferns or Cyperaceae (as the values of Monolete spores without perine and Cyperaceae pollen might indicate). The lake was inhabited by aquatic species of the Ranunculaceae family (e.g. *Batrachium* species), which can be concluded from the high relative values of *Ranunculus acris* type that are too high to originate from regional sources. A similar expansion of aquatic Ranunculaceae is also deducible for several other basins in Vorpommern (Lange et al. 1986, Strahl 1999, De Klerk & Helbig 2006). Such a conclusion is, however, not clearly inferable from the diagram with an „Iversen pollen sum“ (Fig. 5) in which values of the *Ranunculus acris* type are mathematically suppressed by the high values of Cyperaceae and „Wild grass group pollen“. The water was also inhabited by *Botryococcus* and *Pediastrum* taxa. For unknown reasons, the latter disappeared almost completely twice.

Palaeoecological conclusions can hardly be drawn from the few observed diatoms. The scarceness of diatoms is related to increased Si-solution within the basin that attacked the diatoms, to mechanical damage (e.g. by seasonally frozen lake floors), or to an enlarged sedimentation rate connected with the sediment change. The lower AP+NAP concentrations in SPZ REC-F2 indicate that the sediment accumulation rate actually increased during the second sub-phase.

SPZ REC-F3 starts with rises in values of *Empetrum nigrum*, *Juniperus type/Juniperus*-without-gemmae and *Betula nana* type, which shows that the regional vegetation opened-up

further at the beginning of the third sub-phase. This suggests that the lowest temperatures occurred at the end of Open vegetation phase III, as was also observed by De Klerk (2002). It is, however, in contrast with Isarin (1997) and Isarin & Bohncke (1999), who concluded that maximum cold of the Younger Dryas was at its beginning. Another possibility is that the further opening-up of the vegetation relates to changes in moisture regime.

Substantial changes do not occur in the sediment record (Fig. 7), although the largest grain-sizes occur around 120 cm depth and correspond with a maximum in dry-weight and bulk-density. In addition, loss-on-ignition has the lowest values of Open vegetation phase III in this sample. Assumed exotic pollen types, however, remain low. Nevertheless, a maximal erosion event is probably recorded in this sample.

The pollen diagram (Fig. 4) shows that in the middle sub-basin aquatic Ranunculaceae, *Botryococcus* and *Pediastrum* were prominently present. *Pediastrum boryanum* reached a maximum expansion towards the end of the sub-phase.

The level of 17 m a.s.l. represents the minimum height of the water table at the end of Open vegetation phase III, since the highest occurrence of gyttja in the Reinberg is at this level (Fig. 3).

EARLY HOLOCENE BETULA/PINUS FOREST PHASE (SPZ REC-G) – PREBOREAL

SPZ REC-G contains low NAP-values and is, therefore, correlated with the early Holocene. The pollen and macrofossil records show prevailing birch and pine forests that probably included *Populus* (cf. De Klerk 2002). The rise in assumed exotic types in the upper part of SPZ REC-G is due to a rise of *Corylus avellana* type pollen resulting from the immigration of *Corylus* in the regional vegetation: i.e. in fact this type is not exotic anymore.

The sharp transition from gyttja to peat in core REC indicates that a hiatus may include the transition from Open vegetation phase III to the Holocene. A sudden lowering of the water table at the beginning of the Holocene might have caused destruction of the upper lake sediments. Afterwards, water levels rose only slightly and a mire developed in the middle sub-basin. A lake may not have developed because of a reduced water availability resulting from the increased evapotranspiration of

the regional forests. In addition, the better infiltration capacity of the currently thawed soils will have contributed to a reduction of available water in the basin. A similar hiatus (with variable temporal ranges) occurs at many other shallow basins of Vorpommern (De Klerk 2004b).

The pollen diagram further shows that the local mire vegetation in the middle sub-basin contained *Equisetum*, *Filipendula* and *Typha latifolia*. The macrofossils demonstrate additionally the presence of *Drepanocladus* and *Carex*. These *Carex* species must have had low pollen production and/or dispersal capacities, since pollen values of Cyperaceae are relatively low. Abundant sponge needles in the diatom samples between 105 and 90 cm depth show presence of residual water in the peatland. *Nymphaea* and *Potamogeton* inhabited this water, of which the latter is only indicated by macrofossils. *Pediastrum* and *Botryococcus* were very scarce.

CONCLUSIONS

The data presented here provide valuable insights in the development of vegetation and palaeoenvironment in and around a basin in NE Germany. During the late Pleniglacial, an environment of shallow wet ponds and low dry mineral mounds existed with in general rather low water levels. At the beginning of the Lateglacial, temperatures rose probably only slightly, or summer warm periods lasted longer. Consequently water levels rose and a lake formed.

The vegetation development shows a phase with open regional vegetation types, a subsequent phase with prominence of *Hippophaë*, followed by a second phase with an open regional vegetation. The sediment parameter of the Reinberg basin, together with the reconstructed vegetation, point to a gradual shift to a more humid climate. During the *Hippophaë* phase, deposition of CaCO₃ ceased, indicating that decalcification of the soils surrounding the basin had already proceeded to such extent that the interflow had become deprived of lime.

During the Lateglacial *Betula/Pinus* forest phase (Allerød), mainly birch forests prevailed on the dry soils. Soil erosion had greatly diminished, and organic sediments were deposited. A peculiar pollen fluctuation around

the Laacher See tephra indicates short-lived changes in vegetation and environmental parameter as reaction on the eruption of the Laacher See volcano. Silicate input by the tephra favoured development of diatom populations and prohibited solution of diatoms.

Open vegetation phase III (Younger Dryas) shows a tripartition in the opening-up of the regional vegetation. The vegetation was denser and soil erosion was less severe than during the vegetation phases of the early Lateglacial. At the transition to the Holocene a prominent lowering of water levels caused destruction or removal of the upper Lateglacial sediments. After water levels rose again, a peatland developed in the basin.

ACKNOWLEDGEMENTS

Our research was financed by the Deutsche Forschungsgemeinschaft (DFG) – Project Bi 560/1-5 “Specification of the earliest vegetation development at the site Reinberg (time slice I)” within the priority program “Changes in the geo-biosphere during the last 15000 years”, and supervised by Konrad Billwitz. We are grateful to Michael Walther and his colleagues for the coring of core Reinberg C, and to Jürgen Becker, Elisabeth Endtmann, Sabine Helms, Kathrin Krügel, Peter Kühn, and Christian Wünsche for assistance in the field. We thank Hannelore Rabe for the preparation of the pollen samples, Kathrin Krügel for preparation of the sediment samples, and Dierk Michaelis for determination of the macrofossils. Birgit Lintzen and Petra Wiese are thanked for assisting in the preparation of the figures, and Roel Janssen, Hans Joosten, Peter Kühn, Dierk Michaelis, and Susann Stolze for valuable comments on previous interpretations of the Reinberg data. Jürgen Ehlers, Wojciech Granoszewski, Hans Joosten, Bas van Geel, and an anonymous reviewer are kindly acknowledged for commenting on previous versions of this paper.

REFERENCES

- AG BODEN 2005. Bodenkundliche Kartieranleitung, 5. verbesserte und erweiterte Auflage. E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.
- AMMANN B., LOTTER A.F., EICHER U., GAILLARD M.-J., WOHLFARTH B., HAEBERLI W., LISTER G., MAISCH M., NIESEN F. & SCHLÜCHTER, C. 1994. The Würmian Late-glacial in lowland Switzerland. *J. Quaternary Sci.*, 9: 119–125.
- ATKINSON T.C., BRIFFA K.R. & COOPE G.R. 1987. Seasonal temperatures in Britain during the past 22,000 years, reconstructed using beetle remains. *Nature*, 325: 587–592.

- BAT S., OTSCHIRBAT G. & LIGAA U. 1988. Natürliche Vorkommen von Sanddorn in der Mongolischen Volksrepublik. *Gartenbau*, 35: 85–86.
- BIRKELBACH M. & OHLS K. 1995. Schnellbestimmung von tic und toc in Bodenproben. *GIT, Fachz. Lab.*, 12/95: 1125–1128.
- BIRKS H.J.B. & BIRKS H.H. 1980. Quaternary palaeoecology. Edward Arnold, London.
- BIRKS H.H. 1980. Plant macrofossils in Quaternary lake sediments. *Arch. Hydrobiol. Beih. Ergebn. Limnol.*, 15: 1–60.
- BJÖRCK S., WALKER M.J.C., CWYNAR L.C., JOHNSEN S., KNUDSEN K.-L., LOWE J.J., WOHLFARTH B. & INTIMATE MEMBERS 1998. An event stratigraphy for the Last Termination in the North Atlantic region based on the Greenland ice-core record: a proposal by the INTIMATE group. *J. Quaternary Sci.*, 13: 283–292.
- BLUME H.-P., DELLER B., LESCHBER R., PAETZ A., SCHMIDT S. & WILKE, B.-M. (eds.) 2000. *Handbuch der Bodenuntersuchung Band 2*. Wiley-VCH, Weinheim/Beuth, Berlin.
- BOHNCKE S., VANDENBERGHE J., COOPE R. & REILING R. 1987. Geomorphology and palaeoecology of the Mark valley (southern Netherlands): palaeoecology, palaeohydrology and climate during the Weichselian Late Glacial. *Boreas*, 16: 69–85.
- BRANDE A. 1995. Younger Dryas vegetation gradient in northeast Germany. *Terra Nostra Schriften der Alfred-Wegener-Stiftung*, 2/95: 35.
- CHROBOK S.M. 1986. Ursachen und genetische Typen festländischer Kalkbildung periglaziärer und glaziär überformter Räume. *Z. geol. Wiss.*, 14: 277–284.
- COOPE G.R. 1986. Coleoptera analysis: 703–713. In: Berglund B.E. (ed.) *Handbook of Holocene Palaeoecology and Palaeohydrology*. John Wiley and Sons, Chichester.
- DEARING J.A. 1986. Core correlation and total sediment influx: 247–270. In: Berglund B.E. (ed.) *Handbook of Holocene Palaeoecology and Palaeohydrology*. John Wiley and Sons, Chichester.
- DE KLERK P. 2002. Changing vegetation patterns in the Ender Bruch area (Vorpommern, NE Germany) during the Weichselian Lateglacial and Early Holocene. *Rev. Palaeobot. Palynol.*, 119: 275–309.
- DE KLERK P. 2004a. Confusing concepts in Lateglacial stratigraphy and geochronology: origin, consequences, conclusions (with special emphasis on the type locality Bøllingsø). *Rev. Palaeobot. Palynol.*, 129: 265–298.
- DE KLERK P. 2004b. Changes in vegetation and environment at the Lateglacial-Holocene transition in Vorpommern (Northeast Germany). *Internationale Archäologie – ATSK*, 5: 27–42.
- DE KLERK P. 2008. Patterns in vegetation and sedimentation during the Weichselian late-glacial in north-eastern Germany. *J. Biogeogr.*, 35: 1308–1322.
- DE KLERK P. & HELBIG H. 2006. A pollen diagram from a kettle-hole near Horst (Vorpommern, NE Germany) covering the later part of the Weichselian Lateglacial. *Z. Geol. Wiss.*, 34: 379–387.
- DE KLERK P. & JOOSTEN H. 2007. The differences between pollen types and plant taxa: a plea for clarity and scientific freedom. *Eiszeitalter u. Gegenwart.*, 56: 162–171.
- DE KLERK P., HELBIG H., HELMS S., JANKE W., KRÜGELK., KÜHN P., MICHAELIS D. & STOLZES. 2001. The Reinberg researches: palaeoecological and geomorphological studies of a kettle hole in Vorpommern (NE Germany), with special emphasis on a local vegetation during the Weichselian Pleniglacial/Lateglacial transition. *Greifsw. Geogr. Arb.*, 23: 43–131.
- DE KLERK P., JANKE W., KÜHN P. & THEUERKAUF M., 2008. Environmental impact of the Laacher See eruption at a large distance from the volcano: integrated palaeoecological studies from Vorpommern (NE Germany). *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, 270: 196–214.
- ENDTMANN E. 2002. Das „Herthamoor“ - ein palynostratigraphisches Leitprofil für das Holozän der Insel Rügen. *Greifsw. geogr. Arb.*, 26: 143–147.
- ERIKSEN B.V. 2002. Reconsidering the geochronological framework of Lateglacial hunter-gatherer colonization of southern Scandinavia. *Jutland Archaeol. Soc. Publ.*, 39: 25–41.
- FÆGRI K. & IVERSEN J. 1989. *Textbook of Pollen Analysis* (revised by Fægri K., Kaland P.E. & Krzywinski K.). John Wiley and Sons, Chichester.
- FRAHM J.-P. & FREY W. 1992. *Moosflora*, 3rd revised edition. Verlag Eugen Ulmer, Stuttgart.
- FRIES M. & ROSS N.-E., 1950. Pre-Quaternary pollen grains and spores found in late-glacial and post-glacial clays in Bohuslän, SW. Sweden. *Ark. Mineralog. Geolog.*, 1: 199–211.
- FRITSCH GmbH 1994. *Benutzerhandbuch Laser Partikel Sizer „Analysette 22“*. Fritsch GmbH Laborgerätebau, Idar-Oberstein.
- GILLHAM, M.E., 1970. Seed dispersal by birds: 90–98. In: Perring, F. (ed.) *The flora of a changing Britain*. E.W. Classey, Ltd., Hampton.
- GOSLAR T., BAŁAGA K., ARNOLD M., TISNERAT N., STARNAWSKA E., KUZNIARSKI M., CHROST L., WALANUS A. & WIEĆKOWSKI K. 1999. Climate-related variations in the composition of the Lateglacial and Early Holocene sediments of Lake Perespilno (eastern Poland). *Quat. Science Rev.*, 18: 899–911.
- GRIMM E.C. 1992. *TILIA 1.12 and TILIAGRAPH 1.18* (software). Illinois State Museum, Springfield, Illinois.
- GRIMM E.C. 2004. *TGView 1.6.2* (software). Illinois State Museum, Springfield, Illinois.
- GROSSE-BRAUCKMANN G. 1972. Über pflanzliche Makrofossilien mitteleuropäischer Torfe. I. Gewebe-

- reste krautiger Pflanzen und ihre Merkmale. *Telma*, 2: 19–55.
- GROSSE-BRAUCKMANN G. & STREITZ B. 1992. Pflanzliche Makrofossilien mitteleuropäischer Torfe. III. Früchte, Samen und einige Gewebe (Fotos von fossilen Pflanzenresten). *Telma*, 22: 53–102.
- HAMMARLUND D. & LEMDAHL G. 1994. A Late Weichselian stable isotope stratigraphy compared with biostratigraphical data: a case study from southern Sweden. *J. Quaternary Sci.*, 9: 13–31.
- HARWOOD D.M. 1999. Diatomite: 436–443. In: Stoermer E.F. & Smol J.P. (eds.) *The diatoms: applications for the environmental and earth sciences*. Cambridge University Press, Cambridge.
- HARPER M.A., HOWORTH R. & MCLEOD M. 1986. Late Holocene diatoms in Lake Poukawa: effects of airfall tephra and changes in depth. *New Zealand J. mar. Freshwat. Res.*, 20: 107–118.
- HEDBERG H.D. (ed.) 1976. *International stratigraphic guide: a guide to stratigraphic classification, terminology, and procedure*. John Wiley and sons, New York.
- HELBIG H. 1999a. Die spätglaziale und holozäne Überprägung der Grundmoränenplatten in Vorpommern. *Greifsw. Geogr. Arb.*, 17: 1–110.
- HELBIG H. 1999b. Die periglaziale Überprägung der Grundmoränenplatten in Vorpommern. *Peterm. Geogr. Mitt.*, 143: 373–386.
- HELBIG H. & DE KLERK P. 2002. Geoökologische Prozesse des Pleni- und Spätglazials in der Hohlform „Reinberg“, Nordvorpommern. *Greifsw. Geogr. Arb.*, 26: 31–34.
- HELBIG H., DE KLERK P., KÜHN P. & KWASNIOWSKI J. 2002. Colluvial sequences on till plains in Vorpommern (NE Germany). *Z. Geomorph. N.F., Supplementbände*, 128: 81–100.
- HOEK W.Z. 1997. Palaeogeography of Lateglacial vegetations. Aspects of Lateglacial and Early Holocene vegetation, abiotic landscape, and climate in The Netherlands. *Nederl. Geogr. Studies*, 230: 1–147.
- HOEK W.Z., BOHNCKE S.J.P., GANSSSEN G.M. & MEIJER T. 1999. Lateglacial environmental changes recorded in calcareous gyttja deposits at Gulickshof, southern Netherlands. *Boreas*, 28: 416–432.
- ISARIN R.F.B. 1997. The climate in north-western Europe during the Younger Dryas: A comparison of multi-proxy climate reconstructions with simulation experiments. *Nederl. Geogr. Studies*, 229: 1–160.
- ISARIN R.F.B. & BOHNCKE S.J.P. 1999. Mean July temperatures during the Younger Dryas in north-western and central Europe as inferred from climate indicator plant species. *Quat. Research*, 51: 158–173.
- IVERSEN J. 1936. Sekundäres Pollen als Fehlerquelle. Eine Korrektionsmethode zur Pollenanalyse minerogener Sedimente. *Danm. Geol. Unders. IV. Række*, 2: 3–24.
- IVERSEN J. 1954. The late-glacial flora of Denmark and its relation to climate and soil. *Danm. Geol. Unders. II. Række*, 80: 87–119.
- JANKE V. & JANKE W. 1970. Zur Entstehung und Verbreitung der Kleingewässer im nordostmecklenburgischen Grundmoränenbereich. *Arch. Naturschutz Landschaftsforsch.*, 10: 3–18.
- JANKOVSKA V. & KOMAREK J. 2000. Indicative value of *Pediastrum* and other coccal green algae in palaeoecology. *Folia Geobot.*, 35: 59–82.
- JANSSEN C.R. 1973. Local and regional pollen deposition: 31–42. In: Birks H.J.B. & West R.G. (eds.) *Quaternary plant ecology*. 14th Symposium of the British Ecological Society.
- JANSSEN C.R. 1984. Modern pollen assemblages and vegetation in the Myrtle peatland, Minnesota. *Ecol. Monographs*, 54: 213–252.
- JANSSEN C.R. & IJZERMANS-LUTGERHORST W. 1973. A “local” Late-Glacial pollen diagram from Limburg, Netherlands. *Acta Bot. Neerl.*, 22: 213–220.
- JOOSTEN H. & DE KLERK P. 2002. What’s in a name? Some thoughts on pollen classification, identification, and nomenclature in Quaternary palynology. *Rev. Palaeobot. Palynol.*, 122: 29–45.
- JÖRIS O. & WENINGER B. 1998. Extension of the ¹⁴C calibration curve to ca. 40 000 cal BC by synchronizing Greenland ¹⁸O/¹⁶O ice core records and north Atlantic foraminifera profiles: a comparison with U/Th coral data. *Radiocarbon*, 40: 495–504.
- KAISER K. 2002. Bibliographie zur jungquartären Fluß- und Seegenese in Nordostdeutschland – Titel ab 1990. *Greifsw. Geogr. Arb.*, 26: 233–243.
- KAISER K., DE KLERK P. & TERBERGER T. 1999. Die „Riesenhirschfundstelle“ von Endingen: geowissenschaftliche und archäologische Untersuchungen an einem spätglazialen Fundplatz in Vorpommern. *Eiszeitalter u. Gegenwart*, 49: 102–123.
- KALETTKA T. 1996. Die Problematik der Sölle (Kleinhohlformen) im Jungmoränengebiet Nordostdeutschlands. *Naturschutz Landschaftspfl. Brandenburg, Sonderheft Sölle*: 4–12.
- KATZ N. & KATZ S. 1933. *Atlas der Pflanzenreste im Torf*. Staatsverlag für landwirtschaftliche Literatur, Moskau.
- KLAFS G., JESCHKE L. & SCHMIDT H. 1973. Genese und Systematik wasserführender Ackerhohlformen in den Nordbezirken der DDR. *Arch. Naturschutz Landschaftsforsch.*, 13: 287–307.
- KOLSTRUP E. 1979. Herbs as July temperature indicators for parts of the pleniglacial and late-glacial in the Netherlands. *Geol. Mijnbouw*, 58: 377–380.
- KOLSTRUP E. 1980. Climate and stratigraphy in Northwestern Europe between 30 000 B.P. and 13 000 B.P., with special reference to The Netherlands. *Meded. Rijks Geol. Dienst*, 32: 181–253.
- KOLSTRUP E. 1982. Late-glacial pollen diagrams from Hjelm and Draved Mose (Denmark) with a suggestion of the possibility of drought during the Earlier Dryas. *Rev. Palaeobot. Palynol.*, 36: 35–63.

- KÖRBER-GROHNE U. 1964. Bestimmungsschlüssel für subfossile *Juncus*-Samen und Gramineae Früchte. Probleme Küstenforsch. südl. Nordseegebiet, 7: 1–47.
- KRAMMER K. 1992. Pinnularia: eine Monographie der europäischen Taxa. Biblioth. Diatomol., 26: 1–353.
- KRAMMER K. & LANGE-BERTALOT H. 1986. Süßwasserflora von Mitteleuropa 2/1: Bacillariophyceae 1. Teil: Naviculaceae. VEB Gustav Fischer Verlag, Jena.
- KRAMMER, K. & LANGE-BERTALOT H. 1988. Süßwasserflora von Mitteleuropa 2/2: Bacillariophyceae 2. Teil: Bacillariaceae, Epitlemiaceae, Surirellaceae. VEB Gustav Fischer Verlag, Jena.
- KRAMMER K. & LANGE-BERTALOT H. 1991a. Süßwasserflora von Mitteleuropa 2/3: Bacillariophyceae 3. Teil: Centrales, Fragilariaceae, Eunotiaceae. Gustav Fischer Verlag, Stuttgart.
- KRAMMER K. & LANGE-BERTALOT H. 1991b. Süßwasserflora von Mitteleuropa 2/4: Bacillariophyceae 4. Teil: Achnanthaceae, kritische Ergänzung zu Navicula (Lineolatae) und Gomphonema. Gustav Fischer Verlag, Stuttgart.
- KULLMAN L. 2002. Boreal tree taxa in the central Scandes during the Late-Glacial: implications for Late-Quaternary forest history. J. Biogeogr., 29: 1117–1124.
- KUNTZE H., ROESCHMANN G. & SCHWERDTFEGGER G. 1994. Bodenkunde. Ulmer Verlag, Stuttgart.
- LANGE E. JESCHKE L. & KNAPP H.D., 1986. Ralswiek und Rügen. Landschaftsentwicklung und Siedlungsgeschichte der Ostseeinsel. Teil I: Die Landschaftsgeschichte der Insel Rügen seit dem Spätglazial. Akademie Verlag, Berlin.
- LATAŁOWA M. 1999. Late Vistulian vegetation on Wolin Island (NW Poland) – the preliminary results. Quat. Studies in Poland, special issue: 147–156.
- LI MIN, WU SHUCHEN & ZHANG LI 1989. The position of *Hippophae* in soil and water conservation on the loess plateau: 263–268. In: Ma Yingcai, Pan Ruilin, Zhang Zhemin & Zheng An (eds) Proceedings of international symposium on sea buckthorn (*H. rhamnoides* L.) October 19–23, 1989, Xian, China. Xian.
- LI QUANZHONG, LI PEIYUN, CHEN SHAOZHOU, BAI YUZHEN, PU LIXIN & KONG QINJIE 1989. Multiple effects of artificial common seabuckthorn (*Hippophae rhamnoides*) forests in western Liaoning: 288–297. In: Ma Yingcai, Pan Ruilin, Zhang Zhemin & Zheng An (eds) Proceedings of international symposium on sea buckthorn (*H. rhamnoides* L.) October 19–23, 1989, Xian, China. Xian.
- LITT T. & STEBICH M. 1999. Bio- and chronostratigraphy of the lateglacial in the Eifel region, Germany. Quat. International, 61: 5–16.
- LOTTER A.F., EICHER U., BIRKS H.J.B & SIENGENTHALER U. 1992. Late-glacial climatic oscillations as recorded in Swiss lake sediments. J. Quaternary Sci., 7: 187–205.
- LOWE J.J., BIRKS H.H., BROOKS S.J., COOPE G.R., HARKNESS D.D., MAYLE F.E., SHELDRIK C., TURNEY C.S.M. & WALKER M.J.C. 1999. The chronology of palaeoenvironmental changes during the Last Glacial-Holocene transition: towards an event stratigraphy for the British Isles. J. Geol. Soc., 156: 397–410.
- MARSAL D. 1979. Statistische Methoden für Erdwissenschaftler. Schweizbart'sche Verlagsbuchhandlung, Stuttgart.
- MAYLE F.E., BELL M., BIRKS H.H., BROOKS S.J., COOPE G.R., LOWE J.J., SHELDRIK C., SHIJIE L., TURNEY C.S.M. & WALKER M.J.C. 1999. Climate variations in Britain during the Last Glacial-Holocene transition (15.0–11.5 cal ka BP): comparison with the GRIP ice-core record. J. Geol. Soc., 156: 411–423.
- MENKE B. 1968. Das Spätglazial von Glüsing. Ein Beitrag zur Kenntnis der spätglazialen Vegetationsgeschichte in Westholstein. Eiszeitalter u. Gegenwart, 19: 73–84.
- MERKT J. & MÜLLER H. 1999. Varve chronology and palynology of the Lateglacial in northwest Germany from lacustrine sediments of Hämelsee in Lower Saxony. Quat. International, 61: 41–59.
- MOORE P.D. 1980. The reconstruction of the Lateglacial environment: some problems associated with the interpretation of pollen data: 151–155. In: Lowe J.J., Gray J.M. & Robinson J.E. (eds.) Studies in the lateglacial of North-west Europe. Including papers presented at a symposium of the Quaternary Research Association held at University College London, January 1979. Pergamon Press, Oxford.
- MOORE P.D., WEBB J.A. & COLLINSON M.E. 1991. Pollen analysis. Blackwell Scientific Publications, Oxford.
- PALS J.P., VAN GEEL B. & DELFOS A. 1980. Paleoeological studies in the Klokkeweel bog near Hoogkarspel (Noord Holland). Rev. Palaeobot. Palynol., 30: 371–418.
- PEARSON M.C. & ROGERS J.A. 1962. *Hippophaë rhamnoides* L. J. Ecology, 50: 501–513.
- PUNT W. (ed.) 1976. The Northwest European Pollen Flora I. Elsevier, Amsterdam.
- PUNT W. & BLACKMORE S. (eds) 1991. The Northwest European Pollen Flora VI. Elsevier, Amsterdam.
- PUNT W. & CLARKE G.C.S. (eds) 1980. The Northwest European Pollen Flora II. Elsevier, Amsterdam.
- PUNT W. & CLARKE G.C.S. (eds) 1981. The Northwest European Pollen Flora III. Elsevier, Amsterdam.
- PUNT, W. & CLARKE G.C.S. (eds) 1984. The Northwest European Pollen Flora IV. Elsevier, Amsterdam.
- PUNT W., BLACKMORE S. & CLARKE G.C.S. (eds) 1988. The Northwest European Pollen Flora V. Elsevier, Amsterdam.

- PUNT W., HOEN P.P. & BLACKMORE S. (eds) 1995. The Northwest European Pollen Flora VII. Elsevier, Amsterdam.
- PUNT W., BLACKMORE S., HOEN P.P. & STAFFORD P.J. (eds) 2003. The Northwest European Pollen Flora, VIII. Elsevier, Amsterdam.
- RALSKA-JASIEWICZOWA M., VAN GEEL B., GOSLAR T. & KUC T. 1995. The Younger Dryas - its start, development and the transition to the Holocene as recorded in the laminated sediments of Lake Gościąg, Central Poland: 183–187. In: Troelstra S.R., Van Hinte J.E. & Ganssen G.M. (eds) The Younger Dryas. Proceedings of a Workshop at the Royal Netherlands Academy of Arts and Sciences on 11–13 April 1994. Koninklijke Akademie van Wetenschappen, Amsterdam.
- REIMER P.J., BAILLIE M.G.L., BARD E., BAYLISS A., BECK J.W., BERTRAND C.J.H., BLACKWELL P.G., BUCK C.E., BURR G.S., CUTLER K.B., DAMON P.E., EDWARDS R.L., FAIRBANKS R.G., FRIEDRICH M., GUILDERTSON T.P., HOGG A.G., HUGHES K.A., KROMER B., MCCORMAC G., MANNING S., RAMSEY C.B., REIMER R.W., REMMELE S., SOUTHON J.R., STUIVER M., TALAMO S., TAYLOR F.W., VAN DER PLICHT J. & WEYHENMEYER C.E. 2004. Intcal04 terrestrial radiocarbon age calibration, 0–26 cal Kyr BP. *Radiocarbon*, 46: 1029–1058.
- ROUSI A. 1965. Observations on the cytology and variation of European and Asiatic populations of *Hippophaë rhamnoides*. *Annales Bot. Fenn.*, 2: 1–18.
- SALVADOR A. (ed.) 1994. International stratigraphic guide: a guide to stratigraphic classification, terminology, and procedure, second edition. The International Union of Geological Sciences/The Geological Society of America, Inc.
- STEBICH M. 1999. Palynologische Untersuchungen zur Vegetationsgeschichte des Weichsel-Spätglazial und Frühholozän an jährlich geschichteten Sedimenten des Meerfelder Maar (Eifel). *Diss. Bot.*, 320: 1–127.
- STOCKMARR J. 1971. Tablets with spores used in absolute pollen analysis. *Pollen Spores*, 13: 615–621.
- STRAHL J. 1999. Die Vegetationsgeschichte des Herthamoeres in der Stubnitz (Halbinsel Jasmund, Rügen). *Greifsw. Geowiss. Beitr.*, 6: 437–477.
- STUIVER M., GROOTES P.M. & BRAZIUNAS T. 1995. The GISP2 $\delta^{18}O$ climate record of the past 16 500 years and the role of the sun, ocean, and volcanoes. *Quat. Research*, 44: 341–354.
- SUCCOWM. 1988. Landschaftsökologische Moorkunde. VEB Gustav Fischer Verlag, Jena.
- TERBERGER T., DE KLERK P., HELBIG H., KAISER K. & KÜHN P. 2004. Late Weichselian landscape development and human settlement in Mecklenburg-Vorpommern (NE Germany). *Eiszeitalter u. Gegenwart*, 54: 138–175.
- THEUERKAUF M. 2003. Die Vegetation NO-Deutschlands vor und nach dem Ausbruch des Laacher See-Vulkans (12880 cal. BP). *Greifsw. Geogr. Arb.*, 29: 143–189.
- USINGER H. 1985. Pollenstratigraphischer, vegetations- und klimageschichtliche Gliederung des „Bölling-Alleröd Komplexes“ in Schleswig-Holstein und ihre Bedeutung für die Spätglazial-Stratigraphie in benachbarten Gebieten. *Flora*, 177: 1–43.
- USINGER H. 1998. Pollenanalytische Datierung spätpaläolithischer Fundschichten bei Ahrenshöft, Kr. Nordfriesland. *Archäologische Nachrichten aus Schleswig-Holstein. Mitt. Archäol. Gesellsch. Schlesw.-Holst. e.V. u. Archäol. Landesamtes Schlesw.-Holst.*, 8: 50–73.
- VAN DER HAMMEN T. 1951. Late-glacial flora and periglacial phenomena in the Netherlands. *Leidse Geol. Mededelingen*, 17: 71–183.
- VAN GEEL B. 1978. A palaeoecological study of Holocene peat bog sections in Germany and the Netherlands, based on the analysis of pollen, spores and macro- and microscopic remains of fungi, algae, cormophytes and animals. *Rev. Palaeobot. Palynol.*, 25: 1–120.
- VAN GEEL B. 1996. Factors influencing changing AP/NAP ratios in NW-Europe during the Late-Glacial period. *Il Quaternario*, 9: 599–604.
- VAN GEEL B. & KOLSTRUP E. 1978. Tentative explanation of the Late Glacial and Early Holocene climatic changes in north-western Europe. *Geol. Mijnbouw*, 57: 87–89.
- VAN GEEL B., BOHNCKE S.J.P. & DEE H. 1981. A palaeoecological study of an upper Late Glacial and Holocene sequence from “De Borchert”, The Netherlands. *Rev. Palaeobot. Palynol.*, 31: 367–448.
- VAN GEEL B., COOPE C.R. & VAN DER HAMMEN T. 1989. Palaeoecology and stratigraphy of the lateglacial type section at Usselo (The Netherlands). *Rev. Palaeobot. Palynol.*, 60: 25–129.
- VAN LEEUWAARDEN W. & JANSSEN C.R. 1987. Differences between valley and dryland vegetation development in eastern Noord-Brabant, The Netherlands, during the Late Glacial and Early Holocene. *Rev. Palaeobot. Palynol.*, 52: 179–204.
- WALKER M.J.C., BOHNCKE S.J.P., COOPE G.R., O’CONNELL M., USINGER H. & VERBRUGGEN C. 1994. The Devensian/Weichselian Late-glacial in northwest Europe (Ireland, Britain, north Belgium, The Netherlands, northwest Germany). *J. Quaternary Sci.*, 9: 109–118.

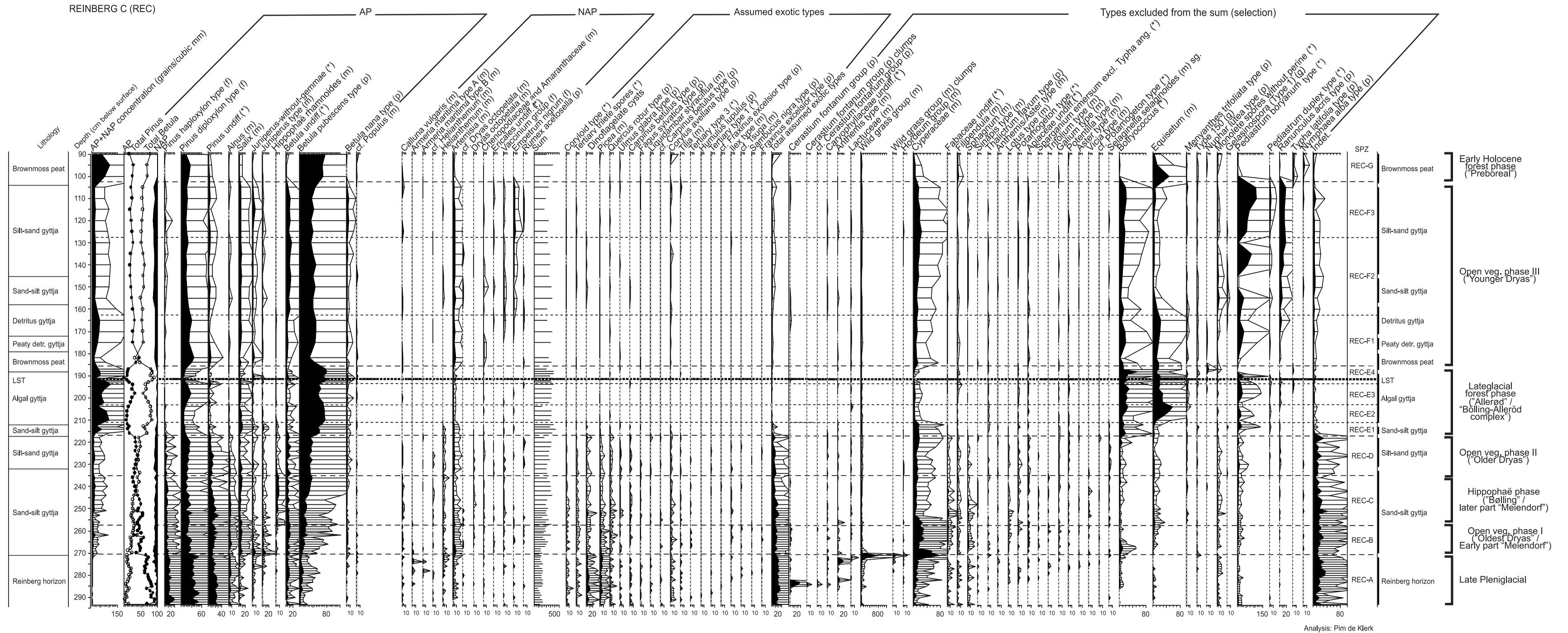


Fig. 4. Pollen percentage diagram "Reinberg C", calculated relative to a regional pollen sum. For pollen type nomenclature (f, g, m, p, *) and calculation of pollen frequencies: see text. Relative pollen values are presented as percentages (closed curves), and a 5-times exaggeration (open curves with depth bars). Pollen types excluded from the diagram are presented in Table 2