FIRST ISOTOPE STUDIES ON THE LATE WEICHSELIAN/HOLOCENE PART OF THE LIMNIC TYPE SEQUENCE FROM THE FORMER LAKE ASCHERSLEBEN (SAXONY-ANHALT, GERMANY)

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Abstract

Isotopic-geochemical pilot investigations were carried out on a limnic sediment sequence from the former Lake Aschersleben in central Germany. Radiocarbon data based on peat and lake marl material cover a time span between approximately 2,560 BP and 17,030 years BP for the drilling cores investigated. The variations in isotope levels characterize the specific lake development such as changes in the temperature regime and the water balance from stable cold climatic conditions in the Upper Glacial period to warmer Late Glacial conditions partly influenced by the influx of glacial water and the rising water level in the Early Holocene.

Key words: lake sediments; stable isotopes; Late Glacial; Holocene; central Germany

INTRODUCTION

The southwestern edge of the Aschersleben anticline features a hollow known as "Seeländereien" containing relatively thick Holocene and Pleistocene sediments. They belong to the former Lake Aschersleben (approximately 12 km × 3 km), which was silted up in ancient times. The original landscape has disappeared owing to the mining of the Tertiary lignite formation below. In 1952, layers of sediment 20–25 m thick were discovered at the edge of Nachterstedt and Königsaue lignite mines. The open walls of the lignite mine showed a sediment profile comprising the entire cycle of the last Glacial from the Eemian to the Holocene. Continuing on from earlier investigations, Mania (Mania 1967a, b, Mania, Töpfer 1973) identified nine thermal fluctuations from the Early Weichselian to the Holocene using mollusc and ostracods fauna as well as various ^{14}C data from organic material. These fluctuations acquired widespread importance and were used to name the various stages of the Weichselian Glacial in central Europe. The Late Glacial in particular contains sedimentation sequences, which seem to characterize climatic development (Mania 1967b). Some information on the vegetation history in this region was derived on the basis of pollen profiles (Müller 1953, Mania 1999).

The potential of working on the open profile is restricted by the fact that the closed mine has been re-cultivated. Nevertheless, the common sequence was able to be studied using modern methods involving drilling cores.

The main objective of this work is to examine the prospects of using the stable isotope method to study the lake sequence of Aschersleben. This approach proved to be successful in our previous studies of the Krumpa limnic Late Glacial sequence from the Geiseltal area (Boettger *et al.* 1998) and the Gröbern Eemian/Early Weichselian profile (Boettger *et al.* 2000) in central Germany, as well as of Ferdynandovian interglacial sequence from Belchatov opencast mine in Poland (Krzyszkowski *et al.* 1996).

METHODS

Sampling

Our first exploratory borings in the area of Lake Aschersleben were carried out in 1999. During the search for an optimal profile, a number of preliminary borings were sunk within the depression approximately 6 km northwest of the town Aschersleben (Fig. 1). The samples for isotope studies were taken from main boring no. 7. This drill core approximately 6 m deep with a diameter of 6 cm was extracted using a Niederreiter Piston Corer. Additionally, some ^{14}C analysis was performed on cores 5 (ca. 1 m depth) and 6 (c. 4.5 m depth) containing peat and sediment largely made up of lim-

Fig. 1. Geologic situation of investigated region (after Hinze *et al.*, 1998) and position of profile Aschersleben. **Holocene**: y – artificial accretion; f – fluviatile sediments; h – moor; **Pleistocene, Weichsel Ice Age:** fl – mud; Lo – loess; **Saale-Ice Age:** sLg – ground moraine; sgf – melt-water deposits; M – middle-, main terrace; **Tertiary:** eo – Eocene; **Mesozoic:** kr – Cretaceous; j – Jurassic; **Triassic:** k – Keuper; mo – upper limestone; mm – middle limestone; mu – under limestone; so – upper bunter sandstone; sm – middle bunter sandstone; rectangle shows the position of the investigated profile.

nic carbonate, and which were extracted using a Russian corer. The distance between the two sampling positions was only approximately 400 m.

Isotope analyses of bulk carbonate

Individual samples were manually cleaned of shells, roots and stones, and then dried (105° C) and sieved (63 µm mesh). The carbonate content was determined with a Coulomat 550 PC made by Ströhlein. The stable isotopic composition of carbonates was measured with a Delta S Finnigan MAT mass spectrometer using the standard phosphoric acid method (McCrea 1950). The isotopic results are shown as

$$\delta = R_{sample} - R_{standard} / R_{standard} \times 1000 \ [\text{‰}];$$
$$R = {}^{13}C/{}^{12}C, \ {}^{18}O/{}^{16}O$$

with respect to the VPDB standard (Vienna standard *Belemnitella Americana* from the Cretaceous Peedee Formation, South Carolina). The reproducibility of the isotope analyses ($\pm 1\sigma$) is better than 0.06‰ for $\delta^{13}C$ and 0.1‰ for $\delta^{18}O$.

Radiocarbon dating of peat and carbonate

Peat samples were pretreated with 4% HCl (80 °C), 2% NaOH (80 °C), 2% HCl at room temperature and the alkali-insoluble fraction was used for further processing. The ^{14}C activities were measured with a Packard Tri-Carb 2560 TR/XL liquid scintillation spectrometer. All ^{14}C data are given in conventional ^{14}C years BP, i.e. corrected for isotopic fractionation by normalizing $\delta^{13}C$ values to –25‰ and then calculated using ANU sucrose and new oxalic acid as reference standards.

RESULTS AND DISCUSSION

Lithology

Leaving aside the ploughed-up soil and an initial core loss, the sediment sequence begins at a depth of approximately 0.80 m with a layer of black peat approximately 0.20 m thick containing numerous plant residues, which then changes into a chalk-free layer of clay and silt, the top of which is humic (Fig. 2). At a depth of 1.20–2.50 m, there are silty/clayey chalk sediments ranging in color from light brown to gray with very different levels of chalk (limnic chalk, chalk mud) and containing molluscs but little in the way of plant residues. After a core loss and starting at a depth of 3.07 m, a 0.18 m-thick layer of clay containing plenty of chalk follows, below which is slightly sandy silt with partly humous deposits and substantial chalk. Silt (gray, occasionally light brown) with high chalk content occurs between 3.60 m and 4.50 m, only the upper section of which contains plant residues. Below a depth of 4.50 m, the sequence then switches to a 0.35 m-thick grayish-olive green layer of fine sand, which at a depth of 4.85–6.25 m is replaced by sandy silt, which is mostly stratified and contains small lumps of lignite but little chalk. The final section down to a depth of 6.38 m consists of a 0.13 m-thick layer of fine to medium sand.

Age determination

Since only a limited amount of organic substance was available for ^{14}C dating, some ^{14}C analyses were also performed on bulk carbonate (lake marl). Six samples from three drilling cores were used, the results being shown in Table 1. The available ^{14}C data provide a very rough time frame and
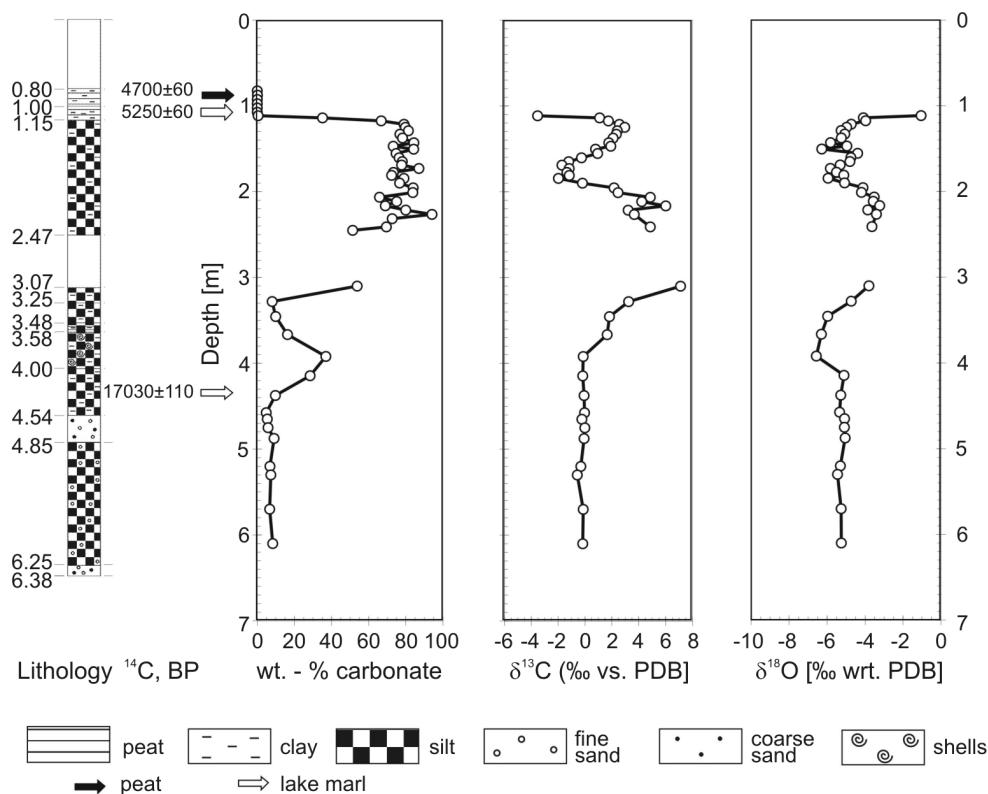
Fig. 2. Main features of the lithology of drilling core no. 7 and summary of contents and stable carbon and oxygen isotope data from lake marl.

reach beyond the Late Glacial. Judging by the age values determined, drill core no. 7 dates back through the Late Glacial into the Upper Glacial period. Laacher See tephra measuring up to a few centimeters was found in some of the older profiles, but could not be visually observed in the investigated drilling cores. The peat accumulation started in early Holocene supporting ^{14}C ages reported by Mania (1967a). Adjacent peat and lake marl samples give rather small age differences (Table 1) and an initial ^{14}C carbonate value of approximately 94 percent modern. Taking the carbonate δ^{13}C-values around 0 ‰ or higher into account, we can suppose a distinct carbon isotope exchange between dissolved inorganic carbon in the lake and atmospheric CO_2 yielding ^{14}C carbonate ages only somewhat too old.

and of the hydrological regime in the lake as inflow-outflow, residence time and evaporation extent of a water body (Talbot 1990). The δ^{18}O composition of the local precipitation is largely a function of surface air temperature: a rather constant long-term isotope gradient of ca. 0.6‰/°C (Rozanski 1992) is characteristic for European precipitation over mid- and high-latitude regions. On the other hand, the carbonate precipitation process leads to a isotope fractionation of ca. –0.24‰/°C (Stuiver 1970). A resulting positive correlation between δ^{18}O of lake carbonate and mean annual air temperature allows to evaluate relative temperature changes if changes in evaporation can be neglected and stable atmospheric circulation existed.

Stable isotope contents of lake marl

Stable isotope analyses of primary carbonates are well suited for paleoenvironmental reconstruction. Carbonates were deposited in isotopic equilibrium with a host solution, but a large number of geochemical and ecological factors may influence the stable isotope distribution of oxygen and carbon in freshwater environments (Bowen 1991). The δ^{18}O value of autochthonous carbonates is determined by the oxygen isotopic composition and temperature of the lake water at the time of carbonate formation. The δ^{18}O value of a lake water reflects the local atmospheric precipitation of the catchment region, which is function of climatic parameters, latitude, altitude and source region (Abell, Nyamweru 1985),

Table 1

List of ^{14}C data of peat and lake marls
(compilation of ^{14}C data from peat and lake marl)

Core no.	Depth [m]	Type of sample	δ^{13}C [‰ VPBD]	14C [BP ± σ]
5	0.90-0.95	peat/lake marl	-26.4	2560±55
6	2.42-2.54	peat	-27.6	7690±65
6	2.54-2.66	peat/lake marl	-25.7	8290±70
7	0.80-0.94	peat	-27.6	4700±60
7	0.95-1.00	lake marl	+2.2	5250±60
7	4.06-4.12	lake marl	-0.4	17030±100

The $\delta^{13}C$ values of autochthonous lake carbonates are mainly controlled by the dissolved inorganic carbon (DIC) in their habitat and give information about its sources (Fritz, Poplawski 1974, Bowen 1991). It depends on ancient environmental conditions in the lake which may be controlled by inorganic input of carbon into the lake and the autochthonous biomass production and its decay in the lake. The decay of organic material with mean $\delta^{13}C$ value of *ca.* –26‰ leads to contribution of the ^{13}C-depleted carbon dioxide to the DIC pool. This process varies according to the trophic state, temperature, and depth, and can also indirectly point to climatic parameters (Deines 1980).

A total of 54 samples were prepared as a rough pattern for stable isotope measurements of limnic carbonate. The findings are shown in Fig. 2. On the whole, what is especially striking is the parallelism between the curves showing the carbonate level, the $\delta^{13}C$ values and the $\delta^{18}O$ values. In the lower part (depth approximately 6.1–4.3 m) of the drilling sequence, the carbonate content remains constantly low (7.1±1.6%). Starting from a depth of approximately 4.3 m, we observe an initial rapid increase in the carbonate level. As of approximately 3.7 m the carbonate level drops again (3.7–3.2 m) down to its initial value before reaching a very high, relatively constant level of approximately 77.5 ± 6.3% as the profile continues between 2.5 and 1.2m. As of a depth of approximately 1.2 m, the carbonate level rapidly declines and the section between 1.0 and 0.8m is free of carbonate.

The $\delta^{18}O$ values remain at the typically constant level for limnic conditions (approximately –5.2 ±0.1‰) until approximately 3.6 m. The $\delta^{13}C$ values also remain constant in this part of profile at approximately –0.2 (±0.2‰). Starting from this depth, we observe a rapid increase in the carbonate level, which is followed by variations in the isotope signatures. At first we observe a pronounced decline in $\delta^{18}O$ values by approximately 1.3‰ (depth 3.9 m, $\delta^{18}O$= –6.5‰). Afterwards, the $\delta^{18}O$ values sharply increase and remain at the level of approximately –3.7 (±0.2 ‰) until a depth of approximately 2 m. A full investigation of the sediment in this range was impossible owing to a drilling core loss between 3.1 and 2.5 m. From a depth of 2.0 m top wards, the $\delta^{18}O$ values become more negative again, varying around –5.2 ±0.5‰ until the top of the profile. As of approximately 1.1 m, carbonate formation ceases and limnic lake chalk turns into peat sedimentation.

The variations in isotope levels closely reflect changes in the temperature regime and the water balance of the lake. The isotope values in the lower section of the profile and the very low carbonate content indicate stable cold climatic conditions from what is still the Upper Glacial time. As of approximately 4.1 m, carbonate production in the lake increases, and the $\delta^{13}C$ values of the carbonate grow heavier; the $\delta^{18}O$ values also follow this trend, albeit with a slight delay. According to Talbot (1990) the apparent lack of covariance between corresponding $\delta^{18}O$ and $\delta^{13}C$ values also suggest an open hydrology in the lake in this time interval. At this time, warmer Late Glacial conditions set in, with the $\delta^{18}O$ values very probably being influenced by the influx of melting water from the receding Weichselian ice cap with characteristic light $\delta^{18}O$ values. Subsequently in the profile, increasing temperatures with the reduced influx of glacial water clearly

dominate the isotope signal of the lake water. Until approximately 1.2 m, the isotope values become more negative again, the carbonate content remaining constant. According to Mania's reconstruction (1967 b), this can be explained by a rising water level, with the lake reaching its greatest size during the Early Holocene. In the upper part of the profile, evaporation affects increasingly the $\delta^{18}O$ values of the shallower lake water. The $\delta^{13}C$ values of lake marl in this part of profile show a strong influence of decaying ^{13}C-depleted organic matter from the lake bottom.

OUTLOOK

Very favorable conditions exist for obtaining sediment cores down to a depth of approximately 10 m depth (Late Glacial/ Holocene) and for complete sediment cores down to approximately 30 m, which can be used to comprehensively document the entire sequence of the Last Glacial from the Eemian to the Holocene using complex palaeoclimatic studies on peat (in mid-Holocene), lake chalk, mollusc series, and organic sediment components (early Holocene-Weichselian-Eemian). In future work, drilling cores of sediments are to be carefully identified and analyzed to enable absolute dating of the climatic variations for the important climatic transitions of the Late Glacial Cycle in central Germany. By ascertaining the geogenic background of climatic variations and ecological changes in the lake basin, it is also expected that these investigations will identify additional criteria for the classification of stratigraphically uncertain cold and warm-period deposits.

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