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THE ^{18}O AND ^{13}C ISOTOPE INVESTIGATIONS OF CARBONATE SEDIMENTS FROM THE LAKE STRAŻYM (BRODNICA LAKE DISTRICT)

Badania izotopami ^{18}O i ^{13}C osadów węglanowych z jeziora Strażym (Pojezierze Brodnickie)

ABSTRACT. Measurements of the ^{18}O and ^{13}C content in lacustrine sediments of the lake Strażym are presented. The discussion considers isotope data obtained from three cores taken out at this lake (Cores No. 3, 6 and 7). The observed fluctuations in the ^{18}O content are interpreted in terms of possible changes in the temperature of the lake during its evolutionary development. Attention is drawn to differences in isotope characteristics of samples taken at various parts of the lake.

THE METHOD

The oxygen-18 and carbon-13 isotope studies on lacustrine sediments started in the early seventies with the aim to reconstruct changes of the temperature of continental lakes in the course of their evolutionary development (Stuvier 1970, Fritz et al. 1975). In recent years several interesting examples of combined pollen and isotope studies covering the Late-Glacial in Europe were published (Eicher et al. 1981, Eicher & Siegenthaler 1983). In the literature it is known sofar only one example of the European lake for which exist complete isotope profiles covering the whole Holocene (lake Tingstäde Trask, Gotland — Mörner & Wallin 1978). In Poland, isotope studies on lacustrine sediments started two years ago. Sofar, cores taken out at four geographically different locations have been analysed (Różański et al. 1986, Różański & Wcisło 1986).

Oxygen-18

The ^{18}O content of the lake carbonate is controlled by the $^{18}O/^{16}O$ isotope ratios of the lake water. The ^{18}O content of water, bicarbonate and carbonate, are related by the known temperature-dependent isotopic fractionation factors, assuming that the thermodynamic equilibrium is maintained during the precipitation of carbonate. If the isotopic composition of water and carbonate is expressed in δ-notation, where δ is defined as a permille deviation from the internationally accepted standards (SMOW for water samples and PDB for carbonates — Craig 1957, 1961), then the lake temperature T (in °C) and the isotopic difference $\delta^{18}O_{carbonate} - \delta^{18}O_{water}$ are related by the following approximate relation:

$$T = 16.1 - 4.21 \cdot \delta^{18}O_{carb.} - \delta^{18}O_{water} \quad (1)$$

Knowing both $\delta^{18}O_{carb.}$ and $\delta^{18}O_{water}$ one can, in principle, calculate the temperature of the lake water characteristic for the period of carbonate precipitation. However, the ^{18}O content of the lake water in the past cannot be directly determined. Therefore, only a very rough assessment of the lake temperature is possible on the basis of eq. (1). Instead of estimating the absolute temperature from eq. (1) one can, however, consider the temperature dependence of $\delta^{18}O_c$, and judge on changes in the lake temperature from variations of the $^{18}O_c$ content in the lake carbonate along the sediment core. The change of $\delta^{18}O_c$ with varying temperature for the European lakes can be characterized by the following gradient (Różański & Wcisło 1986):

$$\frac{\Delta\delta^{18}O_c}{\Delta T} = 0.17 \div 0.43‰/°C \quad (2)$$

Relatively large uncertainty of this value is brought about by poor knowledge of the function transferring fluctuations in the ^{18}O content of precipitation on the given area into changes in isotopic composition of the lake water.

Carbon-13

The interpretation of the $^{13}C/^{12}C$ isotope ratios in lacustrine carbonates is more complicated than is the case of the $^{18}O/^{16}O$ ratios. The ^{13}C content of the lake carbonate is controlled by numerous factors, the most important among them being:
- ^{13}C content of the bicarbonate dissolved in the water feeding the lake,
- degree of exchange between the lake water and the atmospheric CO_2,
- stratification of the lake,
- biological activity of the lake.

The biological activity is often considered as a decisive factor. Due to large kinetic isotope effect during the assimilation process in the lake, the remaining carbonate ions become enriched in ^{13}C. The lake which is in complete equilibrium with atmospheric CO_2 should have the $\delta^{13}C$ value of the dissolved carbonates close to $+2‰$, if other sources of carbon in the lake are insignificant.

The ^{18}O and ^{13}C content of the lake carbonates is measured by the mass-spectrometric method. Details of the preparation and measurement procedures are discussed elsewhere (Wcisło 1985).

RESULTS AND DISCUSSION

The discussion which follows considers two cores taken out in the central part of the lake in 1984 and 1985 (Core No. 6 and Core No. 7). Isotope results from the Core No. 3 excavated in the lake margin were discussed earlier (Różański et al. 1986).

The $\delta^{18}O$ and $\delta^{13}C$ profiles as well as $CaCO_3$ content along these three cores are summarized in Fig. 1. The $\delta^{18}O$ profile for the lake Tingstäde Trask (Gotland) published by Mörner and Wallin (1978) is given also for comparison. For comparison of Mörner's data with the $\delta^{18}O$ profile of the Core No. 6 a constant sedimentation rate was assumed with the minimum in the ^{18}O content at 1010 cm taken as a reference level. The Core No. 7 was taken ca. 40 m apart of the Core No. 6, down to the depth of ca. 5 m. Thus, similar sedimentation rates at the both sites are expected. The depth scales were fitted together by comparing all three profiles measured ($\delta^{18}O$, $\delta^{13}C$ and $CaCO_3$ content). The best fitting was obtained when the Core No. 7 started at the depth of ca. 560 cm on the Core No. 6 scale. It should be noted that comparison of pollen data for the both cores suggests a starting point for the Core No. 7 somewhere at the depth of ca. 650 cm (Noryśkiewicz — this volume). Both the cores reveal high degree of similarity in all three parameters measured, despite of small differences in fine structure of the profiles. Such differences may well be caused by slightly different conditions of sedimentation at the sampled regions of the lake. Large discrepancies in the $\delta^{18}O$ profiles occur only for the uppermost 150 cm of the Core No. 6. It exhibits in this region very large fluctuations with unacceptably low $\delta^{18}O$ values, up to $-12.8‰$. The carbonate with such low ^{18}O content can hardly be produced in the lake under climatic conditions similar to the present ones. Since some sort of analytical error cannot be excluded, the interpretation of this part of the $\delta^{18}O$ curve is postponed until results of repeated measurements will be available.

The bottom part of the $\delta^{18}O$ profile for the Core No. 6 reveals a very distinct transition between Younger Dryas and Pre-Boreal (the layer between 1010 cm and 990 cm), which is in excellent agreement with pollen data. Further downward, small peak in the ^{18}O content occurs, suggesting relatively short period of milder climate within the Younger Dryas period. The transition YD—PB is accompanied by an increase in the ^{18}O content by about $2.5‰$, which corresponds to change in the lake temperature by ca. 8°C, if the mean value of the $\delta^{18}O$/temperature gradient equal to $0.3‰/°C$ is accepted. At the same horizon drastic changes are observed also for the $\delta^{13}C$ and $CaCO_3$ content: $\delta^{13}C$ decreases by about $1‰$ whereas the carbonate content raises sharply from ca. 10% to about 50%. This may indicate fast development of the lake during the YD—PB transition.

The high degree of similarity between the discussed part of the $\delta^{18}O$ profile and that found in the lake Tingstäde Trask is striking. Even the small peak preceeding the YD—PB transition correlates well in the both profiles. It should

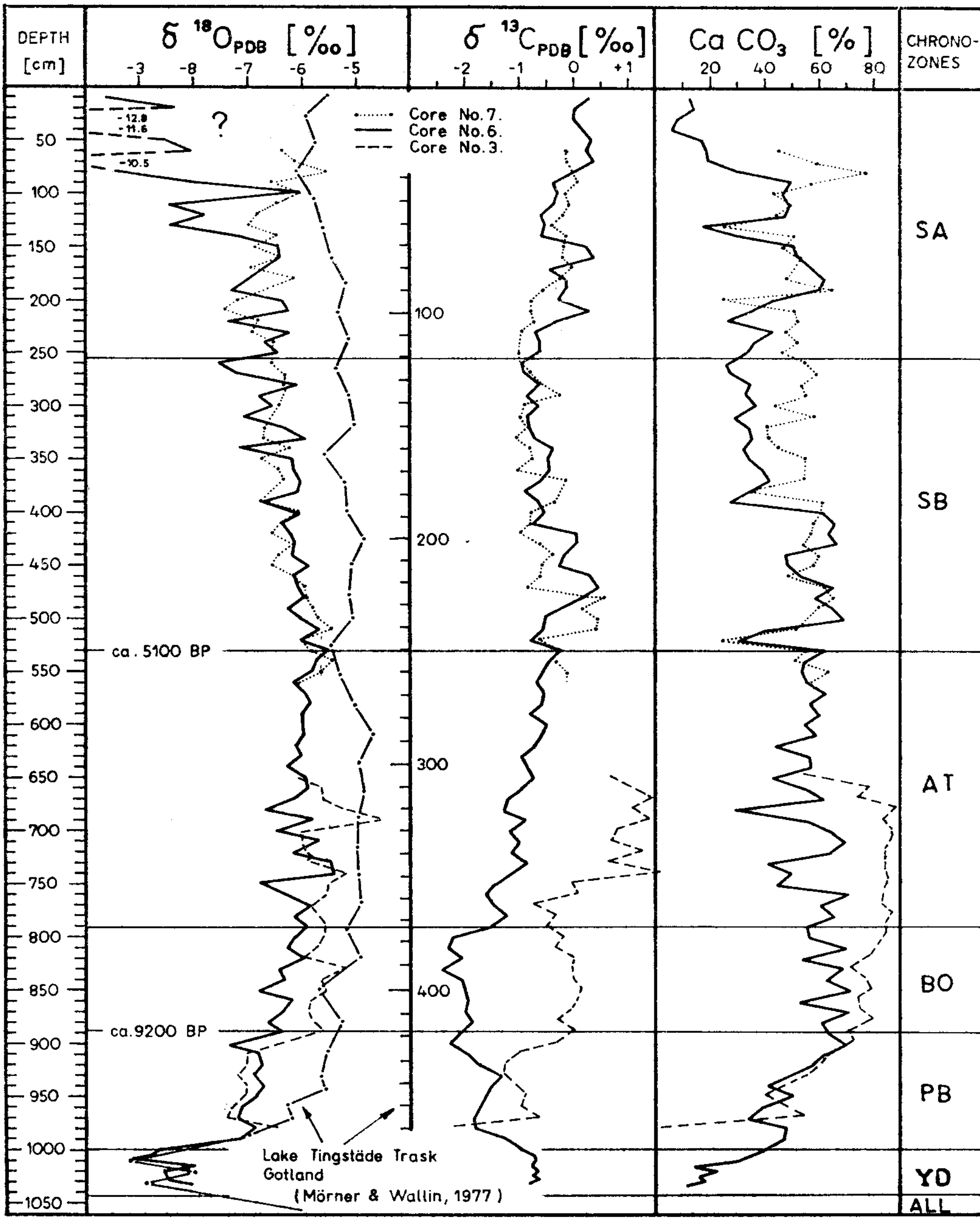

Fig. 1. ^{18}O, ^{13}C and $CaCO_3$ content of carbonate sediments in the lake Strażym

be noted, however, that the main raise in the ^{18}O content in this core was interpreted by Mörner and Wallin (1978) as an indication of the Pre-Boreal--Boreal boundary. They have estimated the corresponding change in the mean summer temperature of the lake Tingstäde Trask as equal to about 7°C, which is close to our estimate for the lake Strażym, but ascribed it to another climatic boundary.

Between the depth of 980 and 730 cm the ^{18}O content in the Core No. 6 increases gradually to ca. −5.8‰, indicating slow improvement of climate and rise of the lake temperature by 2 to 3°C. Further onward the $\delta^{18}O$ curve remains at a roughly constant level, with a culmination at about 530 cm. The age of this level was estimated from pollen data to be about 5100 BP. The upper part of the profile reveals gradual deterioration of climate — ^{18}O content drops from about −5.5‰ at 530 cm to ca. −6.7‰ at about 270 cm, suggesting remarkable cooling by 3 to 4°C. The remaining part of the profile (up to about 150 cm) shows relatively large variability indicating probably unstable conditions of the lake (fluctuations of water level, changes in degree of evaporation, etc.).

The $\delta^{18}O$ profile found for the Core No. 3 (described in earlier publication — Różański et al. 1986) is shown also in Fig. 1. Again, constant sedimentation rate was assumed. The transition Pre-Boreal-Boreal at ca. 9200 BP, visible in the both profiles, serves as a reference level. This profile reveals generally higher variations of the ^{18}O content than observed in the Core No. 6. This may be brought about by the fact that the core was excavated at the lake margin exposed to more unstable environmental conditions than the centre of the lake. This conclusion seems to be supported also by quite different shape of the $\delta^{13}C$ profile.

It is worth to note that general shape of the $\delta^{18}O$ variations found along the Core No. 6 is common for all Holocene cores investigated sofar. Sharp rise of the ^{18}O content at the Pleistocene/Holocene boundary is followed by a stepwise increase of this parameter till ca. 8000 BP, with superimposed shift at the PB—BO boundary at ca. 9200 BP. The absolute maximum of the ^{18}O content in Holocene occurs at ca. 5100 BP. Above this boundary slight, gradual decrease of the ^{18}O content is usually observed.

The $\delta^{13}C$ profile found for the Core No. 6 has a broad minimum between 980 and 800 cm, accompanied by a maximum of the $CaCO_3$ content. This may indicate advanced stage of development of the lake (increasing depth — accumulation started at the lake margin). From 800 cm to about 475 cm gradual increase of the $\delta^{13}C$ is observed, whereas the $CaCO_3$ content remains at roughly constant level. Such trend may be an indication of increasing biological activity in the lake and/or improvement of climate. Starting from the level of ca. 475 cm, the ^{13}C content varies irregularly and slight correlation is observed between $\delta^{13}C$ and the $CaCO_3$ content.

CONCLUSIONS

The discussed above isotope data from the lake Strażym are unique in the sense that they provide information on possible differences in the ^{18}O and ^{13}C content of lacustrine carbonates sampled from the same stratigraphic horizon but from different regions of a given lake. Comparison of the Core No. 6 and No. 3 is especially instructive in this context. The ^{18}O data for the Core No. 6 represent the most detailed and complete $\delta^{18}O$ profile, ranging from the Younger Dryas period till the recent time. The isotope investigations of lacustrine sediments originating from other lakes in Poland are in progess and should bring additional information on the development of climate over this part of Europe during the Late-Glacial and Holocene.

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