ZESZYTY NAUKOWE POLITECHNIKI ŚLĄSKIEJ 1989
Seria: MATEMATYKA-FIZYKA z. 57 GEOCHRONOMETRIA Nr 5 Nr kol. 989

Tomasz GOSLAR

Radiocarbon Laboratory
Silesian Technical University, Gliwice

VARIATIONS OF THE RATIO OF LAMINAE THICKNESSES IN SEDIMENTS OF LAKE GOŚCIĄŻ - A COMPARISON WITH SOME PALAEOTEMPERATURE ESTIMATES

Summary: A hypothesis has been proposed, that changes in ratio of thicknesses of light and light+dark layers in laminated sediment of the Lake Gościąż correspond to the climatic variations. For the period of Holocene there is good similarity between smoothed sequence of the ratio of laminae thicknesses and palaeotemperature reconstructions from the Lake Tingstade Trask, Gotland, and from the Denmark Strait. For the Late Glacial, the changes of ratio of laminae thicknesses correspond to the maxima and minima in cumulative plot of radiocarbon dates from Polish localities. Similarity of curves seems to prove additionally the annual character of lamination in the Lake Gościąż and fix the zero point of chronology at about 13,300 cal BP.

1. INTRODUCTION

Lacustrine sediments are relatively widely used for studies of past climatic changes. Since the work of Stuiver (1970) the ^{18}O method has been successfully applied in palaeoclimatic studies, and several papers presenting results of combined pollen and isotope studies on lacustrine sediments have been published (e.g. Eicher et al., 1981, Eicher & Siegenthaler, 1976, 1983, Morner & Wallin, 1977, Morner, 1980, Punning et al., 1984, Różański, 1988). However, because in most studies the time scale was not available, the results were presented in function of depth instead of time.

Investigation of laminated lacustrine sediments is especially interesting, since such sediments offer relatively precise dating control. Moreover, additional information can be derived directly from changes of varve thicknesses. The correlation between varve thicknesses variation and climate has been firstly found by Seibold (1958). Short-term cyclic variations of varve thickness were correlated with climatic changes (Kempe & Degens, 1979, Renberg et al., 1984). A joint application of three methods mentioned above to investigations of laminated sequence from the Gościąż Lake (Ralska-Jasiewiczowa et al., 1987) seems to offer unique possibility of detailed reconstruction of climatic changes during the Late

Glacial and Holocene. A lot of time is needed, however, to complete pollen and isotopic analyses, while the record of varve thicknesses is obtained immediately in the first stage of research as a result of counting the number of varves. It seems therefore worthwhile to study the information comprised in varve thicknesses already in this initial stage of research.

2. THE RECORD OF RATIO OF LAMINAE THICKNESSES

The chronology of the lower part of laminated sediments of the Gościąż Lake (Goslar et al., 1989) is used in this study to obtain tentative picture of climatic variations immediately from the record of varve thicknesses. The chronology exists in form of three separate records comprising thicknesses of light (l), dark (d) and light + dark (l+d) layers and covers more than 9600 years in four segments. The gap between first and second segment is probably greater than 100 years, while two other gaps are of order of few years.

In the whole sequence a high correlation is observed between thicknesses of light and dark laminae deposited during the same year. This means that the thicknesses of light and dark layers are controlled, to a certain degree, by the same factor or factors (e.g. amount of material input to the lake). It seems that the influence of such factors will be significantly reduced by considering the ratio of light layer thickness to total couplet thickness

$$r = \frac{l}{l + d} .$$

Because thicknesses of light and dark layers represent summer and winter sedimentation, respectively, it is assumed that the ratio r includes an information about duration of period with high temperature, i.e the duration of summer, and, to a certain degree, about mean summer temperature. The interpretation of numeric values of parameter r in terms of definite climatic conditions in not established. In spite of this it is assumed for the purpose of this study to use the terms "warmer" and "cooler" climate as denoting periods with high and low values of r, respectively. The sequence of r values was smoothed by calculating 21-year running averages, and taking average values in successive 50-year intervals. Each point of smoothed sequence corresponds therefore to 50 years. The gaps were filled by adding artifical points with r=0.5 to the original sequence. The zero point of chronology has been assumed to be 13,300 cal BP (Goslar et al., 1989). The obtained record is shown by curve A in Fig. 1.

3. COMPARISON WITH PALAEOCLIMATIC RECONSTRUCTIONS

The Holocene period

For comparison with the sequence of r values were chosen the palaeoclimatic reconstructions available in form of the temperature record with relatively precisely established time scale. It seems that the most

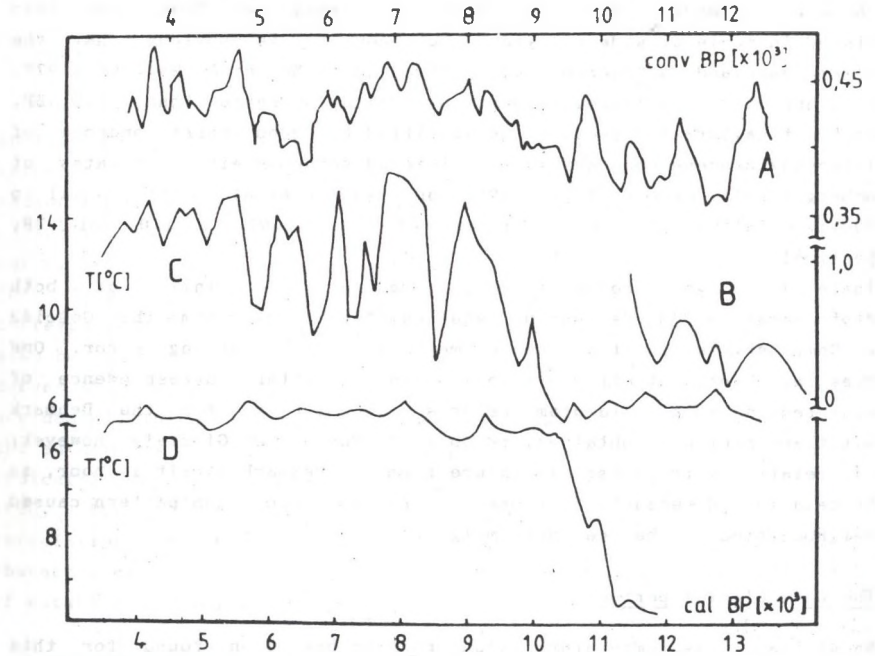

Fig. 1. A comparison between: A - smoothed sequence of the ratio of summer layer to whole varve thicknesses from Gościąż Lake, B - smoothed cumulative histogram of radiocarbon dates of the Late Glacial in Poland (Pazdur & Pazdur, 1986), C - mean summer temperature reconstruction from the Denmark Strait (Kellogg, 1984, core V29-206), D - mean summer temperature reconstruction from Lake Tingstade Trask, Gotland (Morner & Wallin, 1977).

Rys. 1. Porównanie wygładzonej krzywej stosunku grubości lamin z Jez. Gościąż (krzywa A) z krzywą częstości dat radiowęglowych z terenu Polski dla okresu późnego glacjału (krzywa B, wg: Pazdur, Pazdur, 1986) oraz rekonstrukcjami średnich temperatur lata wykonanymi na podstawie rdzenia V29-206 osadów morskich (krzywa C, wg: Kellogg, 1984) oraz na podstawie rdzenia osadów jeziornych z Jez. Tinkstade Trask (krzywa D, wg: Morner, Wallin, 1977).

suitable comparison is provided by the records of mean summer temperature in sediments of Lake Tingstade Trask, Gotland (Morner & Wallin, 1977, Morner, 1980, 1984) and in core V29-206 from the Denmark Strait (Kellogg, 1984). These records are presented in Fig. 1 by curves D and C, respectively. The time scale of both records was constructed by calibration of conventional radiocarbon dates, quoted by the authors, using calibration curves of Stuiver & Pearson (1986), Pearson & Stuiver (1986), Pearson et al. (1986), Kromer et al. (1986) and Stuiver et al. (1986). It should be pointed out that only the first two curves are officially accepted and can be regarded as definite while the last three

are tentative. Nevertheless, it may be expected that only slight corrections of these tentative curves will be made in future.

The palaeotemperature record from Lake Tingstade Trask has been published in scale of sidereal years, but now it is obvious that the sidereal years and radiocarbon years presented by Mörner & Wallin (1977, Figs 12 and 15) do not agree for conventional ages greater than 7000 BP. The present calibration seems to be justified by good correspondence of Pleistocene/Holocene boundary in recalibrated sequence with estimates of Strömberg (1985), Hammer et al. (1986) and Stuiver et al. (1986), equal to 10,700 ± 50 cal BP, 10,720 ± 75 cal BP and 10,970 ± 110 cal BP, respectively.

There is a good correlation of maxima and minima of both palaeotemperature records and the sequence of r values from the Gościąż Lake. Some shifts in time scale may be due to dating error. One interesting point, but difficult to explain, is better correspondence of r-value record with palaeotemperatures reconstructed for the Denmark Strait than with those obtained for Gotland. For Late Glacial, however, the correlation with palaeotemperature from the Denmark Strait is poor, as might be expected because of probably different circulation pattern caused by neighbourhood of the ice sheet margin.

The Late Glacial period

No similar palaeotemperature reconstruction has been found for this period unfortunately. Although the Late Glacial stratigraphy is well recognized, there are some discrepancies if different models are used for reconstruction the climatic changes in this period (cf. Berglund et al., 1984). There are some doubts concerning climate deterioration during the Older Dryas phase, as in some European localities no temperature fall has been noted (cf. Eicher & Siegenthaler, 1976, Oeschger et al., 1980, Kaiser & Eicher, 1987). It seems reasonable to expect significant regional differences of patterns of climatic changes during the Late Glacial period. For that reason, it would be the best to correlate the record from the Gościąż Lake with some reconstruction from Polish area. But, unfortunately, such reconstruction based on continuous Bolling-Allerod profile, is not available yet. The most suitable indicator of climatic changes seems to be the cumulative plot of radiocarbon dates of the Late Glacial period in Poland (Pazdur & Pazdur, 1986), containing 120 dates from 59 localities. Generally, the frequency of dates should resemble the climatic rhythm of stadials and interstadials during the considered period of time. This effect is, however, modified because older sediments are, as a rule, worse preserved, and, additionally, because of purely subjective interests of individual workers. In spite of this, the characteristic features of histogram seem to be the maxima corresponding to the interstadials of Bolling and Allerod, and minima of the Older and Younger Dryas. The smoothed cumulative histogram is presented by cure B in Fig. 1.

There is a good correlation between this histogram and curve of ratio of laminae thicknesses.

4. CONCLUSIONS

The record of ratio of laminae thicknesses from the Lake Gościąż, shown in Fig. 1, is presented in common time scale with some palaeoclimatic reconstructions. In order to adjust the time scale, conventional radiocarbon dates have been calibrated in the same way for all considered palaeclimatic reconstructions. The inherent accuracy of dates, calibration curves, and temperature estimates may be, of course, subject of discussion (cf. Siegenthaler & Eicher, 1985, p. 415). The proposed basis of correspondence between the ratio of laminae thicknesses and climate may also be questioned. In spite of this the correlation between individual curves shown in Fig. 1 is, from purely statistical point of view, not accidental. The possible ground of this dependence is that presented by the author. Validity of the ratio of laminae thicknesses as palaeoclimatic indicator seems to be very promising although it needs more detailed study. On the other hand, it may be concluded that satisfactory correlation of different records shown in Fig. 1 confirms the annual character of lamination in the Gościąż Lake and dating of the zero point of established chronology at about 13,300 cal BP (Goslar et al., 1989).

ACKNOWLEDGEMENTS

This study was supported by grant from the Central Research Project CPBP 03.13

REFERENCES

Berglund B. E., Lemdahl G., Liedberg-Jonsson B., Persson T, 1984, Biotic response to climatic changes during the time span 13,000-10,000 B.P. - a case study from SW Sweden; [In:] Mörner N.-A., Karlen W., Eds, Climatic Changes on Millenium to Annual Time Scales; Reidel, p. 25-36.

Eicher U., Siegenthaler U., 1976, Palynological and oxygen isotope investigations on Late-Glacial sediment cores from Swiss lakes; Boreas, vol. 5, p. 109-117.

Eicher U., Siegenthaler U., 1983, Stable isotopes of oxygen and carbon in the carbonate sediments of Lac de Siguret (Hautes-Alpes, France); Ecologia Mediterranea, vol. 9, p. 49-53.

Eicher U., Siegenthaler U., Wegmüller S., 1981, Pollen and oxygen isotope analyses of the Pourbiere de Chirens (Dauphine, France); Quaternary Res., vol. 15, p. 160-170.

Goslar T., 1987, Dendrochronological studies in Gliwice Radiocarbon Laboratory, equipment, first results; Ann. Acad. Sci. Fenn., AIII, vol. 145, p. 97-104.

Goslar T., Pazdur M. F., Walanus A., 1988, Chronology of annually laminated sediments of Gościąż Lake (lower part); Zesz. Nauk. Pol. Śl., Ser. Mat.-Fiz., (this volume).

Hammer C. U., Clausen H. B., Tauber H., 1986, Ice-core dating of the Pleistocene/Holocene boundary applied to a calibration of the ^{14}C time scale; Radiocarbon, vol. 28, p. 284-291.

Kaiser K. F., Eicher U., 1987, Fossil pollen, molluscs, and stable isotopes in the Dättnau Valley, Switzerland; Boreas, vol. 16, p. 293-304.

Kellogg T. B., 1984, Late-Glacial - Holocene high-frequency climatic changes in deep-sea cores from the Denmark Strait; [In:] Mörner N.-A., Karlen W., Eds, Climatic Changes on Millenium to Annual Time Scales; Reidel, p. 123-133.

Kempe S., Degens E. G., 1979, Varves in the Black Sea and Lake Van (Turkey); [In:] Schluchter C., Ed., Moraines and Varves; Balkema, Rotterdam, p. 309-318.

Kromer B., Rhein M., Bruns M., Schoch-Fischer H., Munnich K. O., Stuiver M., Becker B., Radiocarbon calibration data for the 6th to the 8th millenia BC; Radiocarbon vol. 28, p. 954-960.

Mörner N.-A., 1980, A 10,700 years' palaeotemperature record from Gotland and Pleistocene/Holocene boundary events in Sweden; Boreas, vol. 9, p. 283-287.

Mörner N.-A., 1984, Planetary, solar atmospheric, hydrospheric and endogene processes as origin of climatic changes on the Earth; [In:] Mörner N.-A., Karlen W., Eds, Climatic Changes on Millenium to Annual Time Scales; Reidel, p. 483-507.

Mörner N.-A., Wallin B., 1977, A 10,000 year temperature record from Gotland, Sweden; Palaeogeogr. Palaeoclim. Palaeoecol., vol. 21, p. 113-138.

Oeschger H., Welten M., Eicher U., Moll M., Riesen T., Siegenthaler U., Wegmüller S., 1980, ^{14}C and other parameters during the Younger Dryas cold phase; Radiocarbon, vol. 22, p. 299-310.

Pazdur A., Pazdur M. F., 1986, Radiocarbon chronology of the Late Glacial period in Poland; Acta Interdisciplinaria Archaeol., vol. 4, p. 61-71.

Pazdur A., Pazdur M. F., Wicik B., Więckowski K., 1987a, Radiocarbon chronology of annually laminated sediments from the Gościąż Lake; Bull. Pol. Acad. Sci., Earth Sci., vol. 35, p. 139-145.

Pazdur M. F., Awsiuk R., Goslar T., Pazdur A., Walanus A., Wicik B., Więckowski K., 1987b, Calibrated radiocarbon chronology of annually laminated sediments from the Gościąż Lake; Zesz. Nauk. Pol. Śl., Ser. Mat.-Fiz., z. 56, Geochronometria nr 4, p. 69-83.

Pearson G. W., Pilcher J. R., Baillie M. G. L., Corbett D. M., Qua F., 1986, High-precision ^{14}C measurements of Irish oaks to show the

natural ^{14}C variations from AD 1840-5210 BC; Radiocarbon, vol. 28, p. 911-934.

Pearson G. W., Stuiver M., 1986, High-precision calibration of the radiocarbon time scale, 500-2500 BC; Radiocarbon, vol. 28, p. 839-862.

Punning J. M., Matra T., Vaikemae R., 1984, Light isotope variations in carbonate sediments and their palaeogeographical value; ZfI - Mitteilungen, vol. 84, p. 329-337.

Ralska-Jasiewiczowa M., Wicik B., Więckowski K., 1987, Lake Gościąż - a site of annually laminated sediments covering 12,000 years; Bull. Pol. Acad. Sci., Earth Sci., vol. 35, p. 127-137.

Renberg I., Segerström U., Wallin J.-E., 1984, Climatic reflection in varved lake sediments; [In:] Mörner N.-A., Karlen W., Eds, Climatic Changes on Millenium to Annual Time Scales; Reidel, p. 249-256.

Różański K., 1988, The ^{18}O and ^{13}C isotope investigations of carbonate sediments from the Lake Strażym; Acta Palaeobot., vol. 27, p. 277-282.

Seibold E., 1958, Jahreslagen in Sedimenten der mittleren Adria; Geol. Rundshau, vol. 47, p. 100-117.

Siegenthaler U., Eicher U., 1985, Stable oxygen and carbon isotope analyses; [In:] Berglund B. E., Ed., Handbook of Holocene and Palaeoecology and Palaeohydrology; Wiley, p. 407-422.

Stromberg B., 1985, Revision of the lateglacial Swedish varve chronology; Boreas, vol. 14, p. 101-105.

Stuiver M., 1970, Oxygen and carbon isotope ratios of freshwater carbonates as climatic indicators; Journ. Geophys. Res., vol. 75, p. 5247-5257.

Stuiver M., Pearson G. W., 1986, High-precision calibration of the radiocarbon time scale, AD 1950-500 BC; Radiocarbon, vol. 28, p. 805-838.

Stuiver M., Kromer B., Becker B., Ferguson C. W., 1986, Radiocarbon age calibration back to 13,300 years BP and the ^{14}C age matching of the German oak and US bristlecone pine chronologies; Radiocarbon, vol. 28, p. 969-979.

Recenzent: Prof. dr S. W. Alexandrowicz

Wpłynęło do Redakcji 21 kwietnia 1988 r.

ZMIANY STOSUNKU GRUBOŚCI LAMIN W RDZENIU OSADÓW LAMINOWANYCH Z JEZ. GOŚCIĄŻ I ICH PORÓWNANIE Z ZAPISAMI PALEOKLIMATYCZNYMI

Streszczenie

Wysunięto hipotezę, że zmiany stosunku grubości warstwy jasnej do całorocznej w osadzie laminowanym Jeziora Gościąż związane są z wahaniami klimatu. Dla okresu Holocenu, stwierdzone zostało dobre podobieństwo

miedzy krzywą przedstawiającą wygładzoną sekwencję stosunku grubości warstw a rekonstrukcjami paleotemperatur z Jeziora Tingstade Trask na Gotlandii i z Cieśniny Duńskiej. Dla Późnego Glacjału zmiany stosunku grubości warstw odpowiadają maksimom i minimom na histogramie przedstawiającym częstość dat radiowęglowych z obszaru Polski. Zgodność krzywych wydaje się dodatkowo potwierdzać roczny charakter laminacji oraz wcześniejsze wydatowanie punktu zerowego chronologii z Jeziora Gościąż na ok. 13,300 cal BP.

ИЗМЕНЕНИЯ ОТНОШЕНИЯ ТОЛЩИНЫ СЛОЕВ В ОСАДКАХ ИЗ ОЗЕРА ГОСЦИОНЖ СРАВНЕНИЕ С ИЗБРАННЫМИ КРИВЫМИ ПАЛЕОТЕМПЕРАТУР

Резюме

В докладе рассмотрено предположение, что отношение толщины светлого слоя к суммарной толщине годичного слоя осадков из озера Госционж обусловленно изменением климатических условий в прошлом. Сравнение с избранными кривыми палеотемператур показывает хорошую сходимость между сглаженной кривой отношения толщины слоев и характеристиками палеотемператур в разрезах осадков из озера Тинкстаде Трэск, Готландия, и Датского пролива за период голоцена. Во время позднего гляциала ход полученной кривой коррелирует с диаграммой частоты радиоуглеродных датировок органических образцов с территории Польши. Сходимость этих кривых потверждает годичный характер слоев осадков из озера Госционж.