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CHRONOLOGY OF THE LOWER PART OF ANNUALLY LAMINATED SEDIMENTS OF THE GOŚCIĄŻ LAKE

Summary: The paper presents an attempt of construction of the accurate time scale of lower part of laminated sediments of the Gościąż Lake basing on results of precise measurements of annual layer widths. Thickeness measurements were performed on two cores separately on light and dark layers with the aid of apparatus designed for dendrochronological studies. Accuracy of thickeness measurements is estimated to ca 10%. Results of measurements presented in this article cover 10m thick series of laminated sediments, from its base at depth ca 18.7m to depth ca 8m. Lamination in the upper most part of investigated cores (above 8m) is clearly visible, but frequent disturbances make imposible precise measurements of thicknesses of individual layers with the applied method. Partial sequences obtained on lower parts of cores G1 and G2 were combined into chronology consisting of four segments covering 9682 years. Comparisons with results of measurements of decadal increments performed on core G0 by K. Więckowski and C-14 datings of this core enables to estimate the zero point of obtained chronology to 13,300 cal BP.

1. INTRODUCTION

The exploration of Polish lake sediments, carried by K. Więckowski for more than twenty years led in 1985 to the discovery of a very long, well preserved laminated sediment sequence in Lake Gościąż (central Poland). The 16m long core has been collected in 1m-segments. The number of light/dark couplets along the core has been roughly estimated by K. Więckowski to 12,600 ± 400-600 (Ralska-Jasiewiczowa et al., 1987). Each couplet consists of a light layer with the high content of calcium carbonate, and a dark one with higher content of organic matter. Radiocarbon datings of organic and carbonate fractions of 21 samples from this core and of 2 samples from peat layers found at the base of sediment in two other cores to the annual character of lamination. The value of apparent age of lower part of the core estimated from ^{14}C dates of peat samples (T_{app} = 600 yr; Pazdur et al., 1987a) was inconsistent with the corresponding value obtained from the least square fitting of calibrated ^{14}C dates to the number of varves (T_{app} ≃ 1400 yr; Pazdur et al., 1987b).

Detailed discussion of this problem is presented by Pazdur et al., (1987b).

The sequence of bottom sediments in the Gościąż Lake is the longest laminated sequence known so far (O'Sullivan, 1983; Schove, 1978; Saarnisto, 1985), and covers a significant part of the Late Glacial and the whole Holocene. It offers therefore a unique opportunity for detailed palaeoecological and palaeoclimatological reconstructions. An outline of an interdisciplinary research project was given by Ralska-Jasiewiczowa et al. (1987). The starting point of this project is the construction of the accurate absolute time scale. An attempt of such reconstruction is the subject of this study.

2. MATERIAL

Four cores (G1, G2, G3 and G4) were collected in 1987 by K. Więckowski from bottom sediments of the Gościąż Lake. All cores were more than 16m long and were taken in 2m segments. Distance between sampling places of cores G1, G2 and G3 is equal to ca 5m. In order to provide overlapping of laminated sequences in cores G1 and G2 the segments of G2 core were shifted by 1m in depth scale with respect to those of G1. During taking of 13-15m segment of G2 core, however, it broke off and only its upper part 1m long was taken. The lower part was taken in the next step in form of 14-16m segment. The segments of lower part of both G1 and G2 cores are shown on the depth scale in right-hand side of Fig. 1. The cores G3 and G4 have been taken for palaeomagnetic research, performed at the University of Lund by P. Sandgren.

3. VISUAL FEATURES OF LAMINATION

Because of visible differences in the character of lamination along the cores several sections can be distinguished (all sediment depths given below correspond to G2 core):

1). 18.7m - 18.4m: rather thin, but fine and regular layers.
2). 18.4m - 17.75m: sandy layer with no visible lamination.
3). 17.75m - 16.50m: less regular layers with less black-white contrast.
4). 16.50m - 13.50m: very regular varves, with good contrast and high variability of brightness of light and dark layers. In this part visual correlation between sequences of different cores is the easiest.
5). 13.50m - 11.50m: layers are very thin, a little bit wavy and with no characteristic features of individual dark layers.
6). 11.50m - 8m: rather regular, thicker varves, with constant distinct contrast of all light and dark layers.

Above 8m the layers are often bent and in many places hardly visible. The exact counting by the method used in this study was rather impossible.

For that reason this paper presents the chronology reconstructed for the lower part of sediment, containing sections 1 and 2 - 6.

4. MEASUREMENTS

The surface of both cores was thoroughly cleaned and photographed, so about 800 negatives in scale 1:2 have been obtained.The measurements of layers' thickness were performed on the negatives using the apparatus designed for dendrochronological research (Goslar, 1987). The accuracy of apparatus has been improved to 0.01mm, in this way the resulting accuracy was equal to 0.02mm. The location of boundary of individual of layers was determined with the accuracy of 0.05mm what gives the relative accuracy of layer thickness measurement equal to 10%. Thickness measurements were performed separately for light and dark layers of each couplet. In order to improve the reliability of identifying of the individual layers, two cores were analysed simultaneously, and already before measurements the layers in both cores were correlated by eye. In the sections where the layers were not exactly parallel to one another (wavy or slightly disturbed) measurements were performed along two lines regarded as the most representative for the whole core surface and the results were averaged. In sections where the lamination was seriously disturbed, mostly near the ends of segments, the measurements were not done. The sections of both cores covered by thickness measurements are shown on the scale of number of varves in the upper part of Fig. 1.

In order to check the results obtained on cores the photos of the core G0 collected in 1985 were also analysed,in addition to the negatives of G1 and G2 cores. Their quality is insufficient for measurements of varve thicknesses, but, in spite of this they enable exact visual correlation of varved sequence of core G0 with those of G1 and G2. Radiocarbon dates performed on samples collected from core G0 can be therefore directly transferred to cores G1 and G2.

5. RESULTING CHRONOLOGY

The partial sequences obtained on lower parts of cores G1 and G2 have been combined into one chronology consisting of 4 segments with 9682 couplets shown at the lower part of Fig. 1. The method of combining data from cores G1 and G2 is explained in Fig. 2, representing the surrounding of point B in Fig. 1. In core G1 the thickness of laminae have been measured up to varve no. 290 and from 370 to 432. The gap between varve 290 and 370 is caused by a real gap between segments of this core, while the sequence above varve 433, too much disturbed to be measured. On the other hand, in core G2, it was possible to measure thicknesses in the relatively long sequence above the varve 281. In the resulting chronology

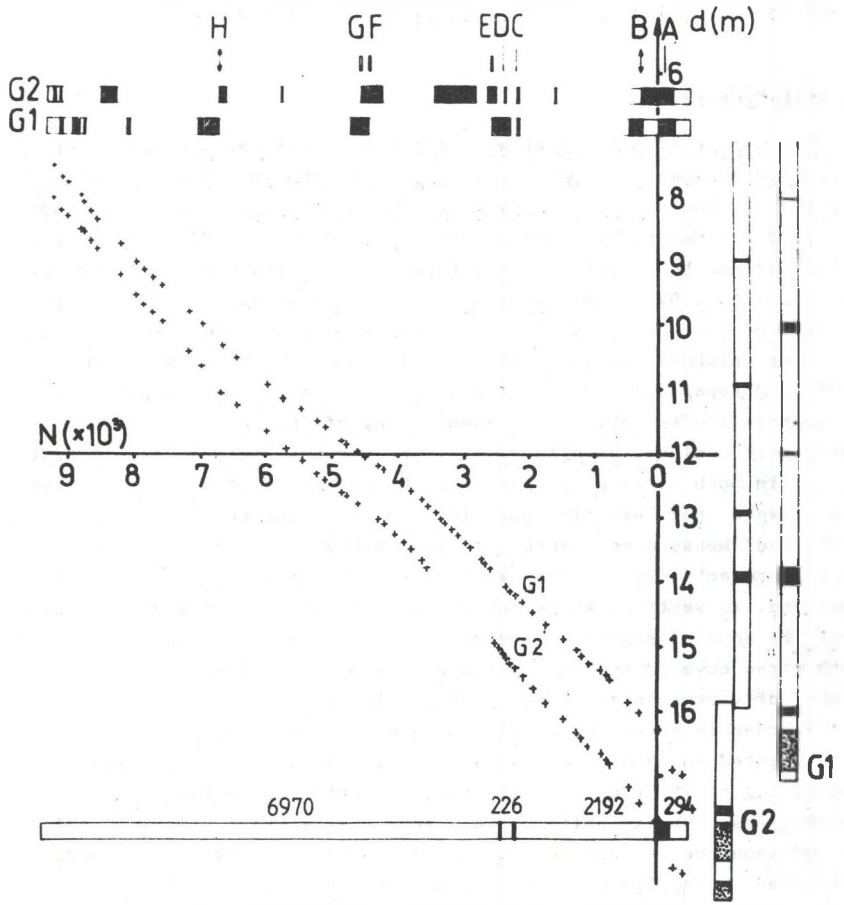

Fig. 1. The chronology of lower part of laminated sediment of the Gościąż Lake. N - number of varves, d - depth below the present day water-sediment interface. Right-hand side - the segments of G1 and G2 cores, upper part of figure - the sections with measured layer thicknesses, lower part of figure - resulting chronology; figures denote numbers of couplets in corresponding segments. The letters A, ... ,G denote the gaps and weak points which are described in details in the text.

Rys. 1. Chronologia dolnej części osadów laminowanych z Jez. Gościąż. N - liczba lamin rocznych, d - głębokość poniżej współczesnego dna jeziora. Po prawej stronie rysunku przedstawiono pobrane segmenty rdzeni G1 i G2, u góry odcinki rdzeni objęte pomiarami grubości lamin, część dolna rysunku przedstawia opracowaną chronologię. Liczby w dolnej części rysunku oznaczają liczby lamin rocznych zawartych w poszczególnych odcinkach tworzących chronologię, symbole literowe A,...,G oznaczają opisane w tekście przerwy i słabe miejsca chronologii warwowej.

the thicknesses of varves 282-290 and 370-432 from of both cores were averaged, while for other sections only results of thickness measurements from single core have been used. As the thickness of light and dark layers was treated separately, and the resulting chronology was constructed in form of three separate sequences (light, dark and light + dark). The short overlap (282-290) is a weak point of chronology. All the gaps and uncertainties of resulting chronology are denoted in Fig. 1 by letters A...H and are discussed below.

1. Gaps with unknown number of varves

A. This gap is represented by >0.5m layer of sand. The lamination at the top of underlying sequence seems to be partly destroyed and in G2 core more varves than in G1 were suitable for measurements. The overlying sequence starts from the same varve in both cores. We expect that this event was of not very long duration. The G0 core doesn't reach this lowermost sequence. For this reason the zero point at the scale of number of varves in Fig. 1 was set to the beginning of overlying sequence.

C. A >5mm thick blue-grey massive layer occurs in all the analysed cores. The overlying sequence starts in all the cores from the same varve. The lamination in the top of underlying sedimnets is disturbed. The underlying sequence in the core G0 reaches 5 varves higher than in G2 and 10 varves higher than in G1 and only in G0 the uppermost layer of this sequence seems to be undisturbed. It can be then assumed that in G0 gap C contains no more than 5 years. In the Fig. 1 the number of varves of G0 core is noted, although measured sequence is a little shorter.

D. A similar massive layer as in C, together with some disturbance caused probably by the break of segment 13-15m during pulling out the corer (see above). Unfortunately, there is no corresponding photo available of the G0 core. The overall thickness of this gap (1.5cm) seems to show that it does not cover more that ca 15 varves.

2. Gaps with known number of varves

E. The disturbance caused by the break of segment 13-15m in G2. The number of varves in this gap have been evaluated with the help of the G0 photos (35 varves).

F. This gap is caused by the fact that the pauses between segments of cores G1 and G2, although occuring at different depths, occur for nearly the same varves. Filled with the help of G0 (7 varves).

G. Break, filled by G0 (39 varves).

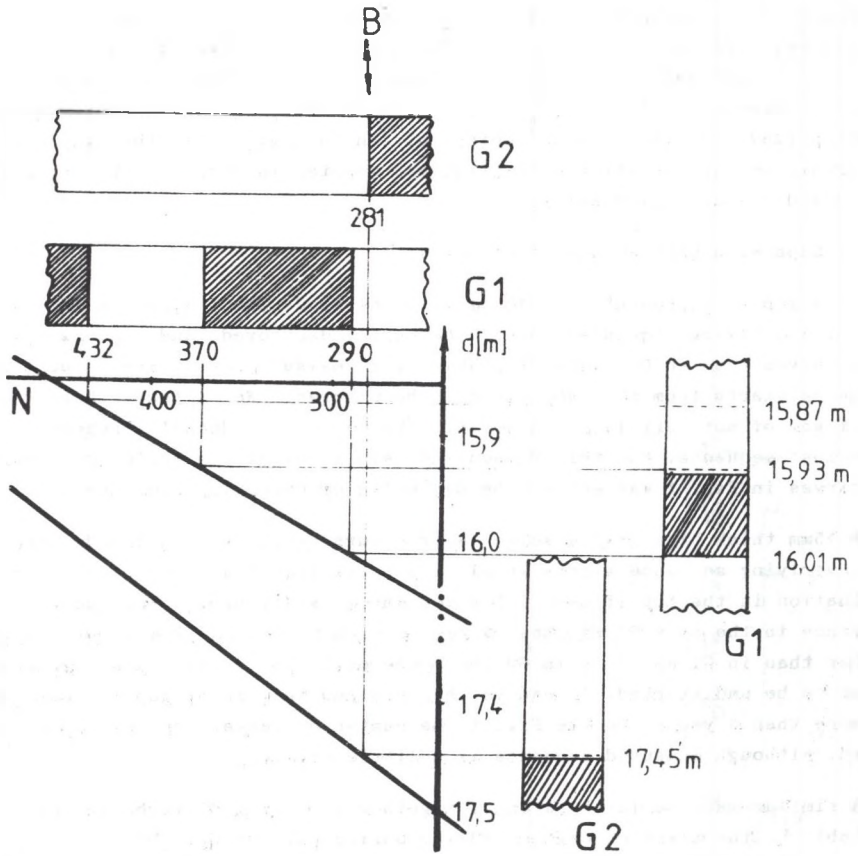

Fig. 2. The illustration of the method used for construction of the chronology. N - number of varves, d - depth below lake bottom. Lower part of figure - plot of thicknesses of light layers of both cores and the chronology. The explanations to the right-hand side and upper part of figure are the same as in Fig. 1.

Rys. 2. Ilustracja metody tworzenia chronologii. N - liczba lamin rocznych, d - głębokość poniżej dna jeziora. Dolna część rysunku przedstawia wykres grubości warstw jasnych i otrzymaną chronologię. Pozostałe objaśnienia jak na rys. 1.

3. Uncertainties

B. This weak overlap (9 years) is caused by the fact that, similarly as in the case of the gap F, the contacts between segments in both cores cover the same varves. The depth relation and characteristic features of varves, however, seem to prove the overlap. It seems to be additionally confirmed by comparison with the results of G3 core (discussed below).

H. A short overlap (36 varves) of the same cause as in F. Confirmed by G0.

In the upper parts of cores, above the continuous sequence the lamination also exists, but the layers are often bent and in many places hardly visible. We hope that the more reliable counting of laminae will be possible with the help of X-ray photographs. In the uppermost 2m of cores only single varves are visible by eye. However, the short frozen cores collected by M. Saarnisto in October 1987 show clearly that lamination reaches the very top of sediment. The reconstruction of time scale in the upper part of sediment will be the subject of the future study.

6. COMPARISON WITH OTHER ESTIMATES

The varves of the whole resulting sequence have been counted once again with unarmed eye on the photos of G1 and G2 cores. The overall number was smaller by 110 laminae than estimated above. The difference may be caused by some double varves counted previously as single ones, but, more probably, it is because some varves were not noticed during quick second counting.

The number of varves corresponding to the resulting sequence has been estimated by K. Więckowski to 12,500 (Ralska-Jasiewiczowa et al., 1987). However, it must be stressed, that the sequence analysed by Więckowski does not reach the lowermost 294 varve sequence. The reason of the remaining difference is that Więckowski has counted only the varves occuring in segments of G0 and the numbers of varves corresponding to the gaps were not available to him. The main source of discrepancy is the gap caused by loss of 40cm of 8 - 9m segment of G0 core. The detailed analysis shows that in the sections where the varves of G0 were counted the results are nearly the same as estimated in this work.

The resulting varve sequence has also been compared with the results of measurements of the whole (light + dark) couplets in G3 core performed by P. Sandgren (Lund University) with the aid of equipment used at dendrochronological laboratory by Th. Bartholin (pers. comm.). The comparison, made on 21-year running averages of light + dark laminae thickness in the sequence described above and in segments measured by P. Sandgren shows overall difference of about 50 varves. It should be also pointed out that in the upper 2000 varves of described chronology the difference is equal to about 5 varves.

6. RELATION BETWEEN NUMBER OF VARVES AND NUMBER OF YEARS

The comparison of radiocarbon age with the number of varves estimated by K. Więckowski has shown approximately one-to-one correspondence. The only doubt concerned the difference between assumed and estimated apparent ages in the lower part (see Introduction). It seems that, basing on resulting chronology we may regard the estimated apparent age (T_{app} = 600 yrs) as real and assume that the zero point of chronology (Fig. 1) corresponds to about 13,300 cal B.P. The annual character of varves seems to be additionally confirmed by comparison with some palaeoclimatic records (Goslar, 1989, this volume). Therefore, the uppermost varve in the counted sequence would correspond to about 3900 cal B.P. The exact analysis, however, will be done after the reconstruction of the whole varve sequence.

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REFERENCES

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

O'Sullivan P. E., 1983, Annualy-laminated lake sediments and the study of Quaternary environmental changes-a review; Quaternary Sci. Rev., vol. 1, p. 245-313.

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 No. 4, p. 69-83.

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.

Saarnisto M., 1985, Annually laminated lake sediments; [in:] B.E. Berglund, Ed., Handbook of Holocene Palaeoecology and Palaeohydrology; p. 343-370.

Schove D. J., 1978, Tree-ring and varve scales combined, c. 13500 B.C. to A.D. 1977; Palaeogeography, Palaeoclimatology, Palaeoecology, vol. 25, p. 209-233.

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CHRONOLOGIA DOLNEJ CZĘŚCI ROCZNIE LAMINOWANYCH OSADÓW Z JEZIORA GOŚCIĄŻ

Streszczenie

Artykuł przedstawia próbę skonstruowania dokładnej skali czasowej dla dolnej części osadów laminowanych z Jeziora Gościąż na podstawie precyzyjnych pomiarów grubości warstw rocznych. Badaniami objęto dolną serię osadów laminowanych od ich spągu do głębokości ok. 8m. Laminacja występująca w części górnej badanych rdzeni jest wyraźna, jednak jej zaburzenia uniemożliwiają dokładne pomiary rocznych przyrostów zastosowaną metodą. Pomiary grubości wykonywane były na dwóch rdzeniach, oddzielnie dla warstw jasnych i ciemnych, za pomocą urządzenia skonstruowanego do prac dendrochronologicznych. Dokładność pomiarów grubości oszacowana jest na ok. 10%. Sekwencje cząstkowe, otrzymane z rdzeni G1 i G2 zostały połączone w chronologię obejmującą 9682 lata w postaci czterech segmentów. Porównanie z wynikami pomiarów wielkości dziesięcioletnich przyrostów wykonanych na rdzeniu G0 przez K. Więckowskiego, oraz wyników datowań metodą ^{14}C tego rdzenia, prowadzi do oszacowania wieku punktu początkowego opracowanej chronologii na 13,300 cal BP.

ХРОНОЛОГИЯ НИЖНЕЙ ЧАСТИ ГОДИЧНО РАССЛОЕННЫХ ОСАДКОВ ИЗ ОЗЕРА ГОСЦИОНЖ

Резюме

В докладе представлена попытка определения детальной временной шкалы для приосновной части слоистых осадков из озера Госционж на основании результатов измерений толщины годичных слоев. Исследования были проведены начиная с основания слоистых осадков на глубине 18.7m до глубины 8m. В верхней части выше 8m осадки также четко расслоены, однако нарушения регулярной слоистости делают невозможным проведение надежных измерений

толщины индивидуальных годичных слоев. Измерения толщины годичных слоев были проведены одновременно в колонках G1 и G2 при использовании оптического прибора для дендрохронологических исследований. Измерения толщины проводили отдельно для светлых и темных слоев составляющих годичное приращение осадка. Точность измерений толщины приблизительно равна 10%. На основании последовательностей полученных из колонок G1 и G2 составлена хронологическая шкала состоящая из четырех сегментов, охватывающих 9682 лет. Сравнение с результатами измерений толщины десятилетних приращений проведенных К. Венцковским для колонки G0 и результатами радиоуглеродного датирования этой колонки свидетелствует, что начало полученной хронологии имеет абсолютный возраст 13 300 cal BP.