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PERIODICITIES IN SEQUENCE OF LAMINAE THICKNESSES IN LAMINATED SEDIMENTS FROM THE GOSCIĄŻ LAKE

Summary: The method of running phase analysis was applied to searching for cyclicities in the sequence of laminae thicknesses of annually laminated sediments from the Gościąż Lake. Analysed sequence covers ca 10,000 couplets in form of seven subsequences, separated with gaps of either unknown or estimated duration. It was found that fundamental statistical characteristics of the individual analysed subsequences are approximately constant. As suggested by other evidence, searching for cyclicity was performed for selected values of periods, equal to 11 yr and 22 yr (the solar cycles), 35 yr (the Bruckner cycle) and 200 yr. The results of running phase analysis indicate the presence of cyclicities corresponding to values of periods listed above. The problem of the significance of revealed cyclicities in the whole sequence was not solved and needs further detailed studies.

1. INTRODUCTION

The sediments of the Lake Gosciąż (Ralska-Jasiewiczowa et al., 1987) consist of about 13,000 couplets of light and dark laminae. Radiocarbon datings on core G0 (Pazdur et al., 1987) and other evidence, including the results of this study (dealing with cores G1 and G2), indicate annual character of lamination, what means that the 1 yr periodicity is evident in the sediment. The structure of upper part of cores (up to ca 2m in depth) is disturbed. The youngest unconsolidated sediment, collected with aid of the cold-finger sampler by M. Saarnisto (Saarnisto, 1985) is also laminated, although the thicknesses of annual increments in this core were not measured.

The laminae thicknesses were measured with aid of the dendrochronological apparatus (Goslar, 1987). The final results consist of sequences of separately measured thicknesses of light and dark laminae. There are several gaps in those sequences, which are of known, estimated or unknown duration. For most of the laminae it was possible to measure their thicknesses in both available cores (G1 and G2; cf Goslar et al., 1989), so the thicknesses used for analysis in this study are averaged from two sequences.

2. GENERAL STATISTICAL CHARACTERISTICS OF SEQUENCES OF LAMINAE THICKNESSES

Because of mentioned gaps in cores G1 and G2 the analysed data sequence consists of 7 continuous subsequences. As the gaps are caused by reasons completely independent of the statistical analysis, the subsequences may be treated as randomly obtained. Their statistical characteristics listed in Table 1 may be therefore regarded as representative.

Table 1

Statistical parameters of individual subsequences of laminae thicknesses; n - number of couplets in the subseries, i. e. time span of of the subseries (in years); d - average thickness of yearly (light+dark) laminae; s - dispersion around the average; a - coefficient of assymmetry; α - randomness test result; τ - length of the gap between the actual and the next subseries (after Goslar et al, 1988).

No.	n	$\bar{d}$ [mm]	s [mm]	a	α	τ [yr]
1	293	0.601	0.20	3.6	0.014	0-500*
2	2186	1.043	0.33	1.2	0.00000005	6-15*
3	225	1.198	0.26	0.1	0.44	0-20*
4	140	1.122	0.21	0.1	0.87	34**
5	1912	0.979	0.23	0.5	0.00003	7**
6	55	0.865	0.18	1.2	0.22	39**
7	4783	1.044	0.31	1.2	0.0000008	-
1-7	9594	1.022	0.31	1.1	-	-

*) assumed value; exact duration of gap is unknown;

**) duration of the gap estimated from data of core G0 (cf Goslar et al, 1988)

The high stability of the whole series of laminae thicknesses is evident from Table 1. The average thicknesses and values of dispersion and coefficient of assymmetry are almost the same for all subseries, excluding the oldest one (No. 1 in Table 1). The average value of thickness for the whole series is almost equal to 1 mm.

The coefficient of assymetry in long series is about 1.2. Positive assymmetry is an obvious feature of every length as layers can be arbitrarily thick, but can not be thinner than 0. After symmetrization by calculating logarithm of thicknesses the coefficient of assymmetry becames zero in all subsequences. This simple result seems to contain some environmental information, as it suggests some kind of symmetry of extremely favorable and unfavorable conditions of sedimentation.

The simple test of randomness based on the number of extremes in the series (Kendall, Stuart, 1966) was applied to each subsequence in order to check the presence of autocorrelation of thicknesses of individual couplets. It gives answer if the so called "null hypothesis" about mutuall independence of laminae thicknesses is false. In Table 1 the significance level is given i.e. the probability of obtaining actual series under assumption of validity of null hypothesis. The low value of this probability makes one to expect the presence of a certain pattern in the series.

3. SEARCHING FOR THE CYCLICITY

Out of different methods tested for the analysis of time series the method of running phase analysis (RPA), introduced by the author (Walanus, 1988) was chosen as the most appropriate for the present study. The method is based on the idea of Fourier Analysis performed in a running manner. The analysis was performed for strictly defined values of periods, equal to 11 yr, 22 yr, 35 yr and 200 yr. The first two values (11 and 22 yr) were chosen to account for the well known solar cycle, next value of 35 yr, which is known as the Bruckner cycle (Bruckner, 1890), was suggested by results of Renberg et al., (1984). The last value was chosen according to results of Neftel et al., (1981). The results of running phase analysis performed for each of periods listed above are shown in Fig. 1 in form of two plots, representing changes of the amplitude (upper plot) and phase (lower plot). The height of the upper plot is related to the amplitude of oscillations in data series; high values indicate presence of periodic component. The lower plot shows changes of the phase of the cycles in a considered interval of time. As the phase can assume values ranging from 0 to T (where the T is the value of period), and 0 is equivalent to T, jumps of phase from the lowest value (0) to the highest (T) are not real jumps in fact. Fragments of the series with stable phase may be treated as containing periodic component. The most important are fragments with the high value in upper plot and the stable phase. A good example can be found in the middle of the last longest subsequence of the plot of 22 yr cyclicity in Fig. 1.

Continuously changing phase confirms the presence of cyclicity and indicates that the real value of the period slightly differs from the value assumed in the RPA method. It must be mentioned that RPA in this study was performed with averaging over 5 neighbouring cycles (or 3 in the case of the longest period of 200 yr). It means that the values in the upper and lower plots, for the 5 (3) consecutive cycles are not independent.

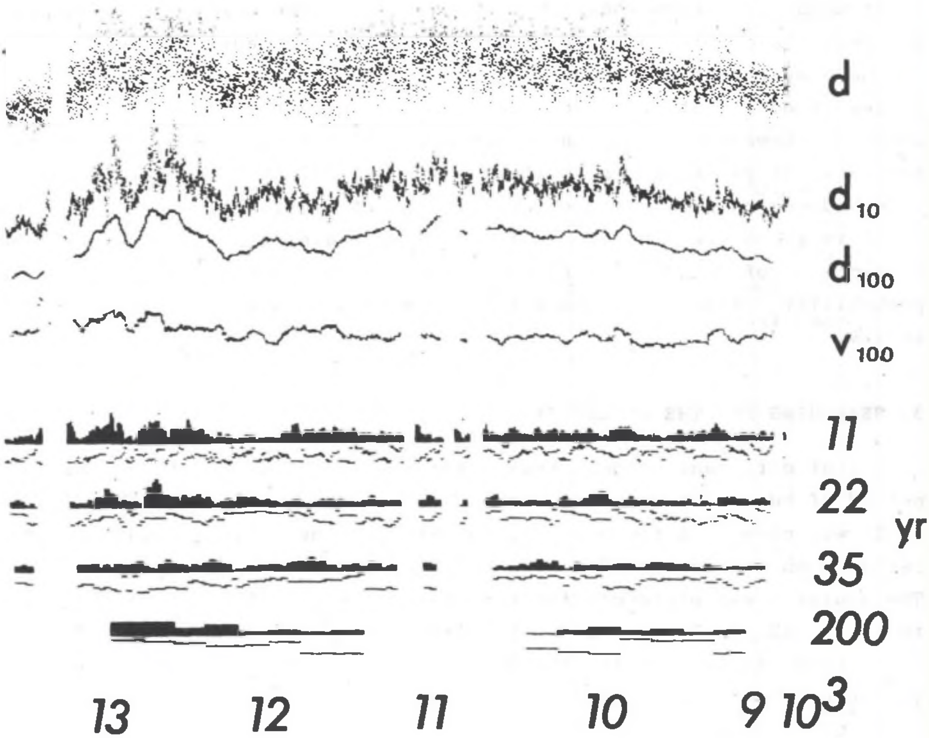
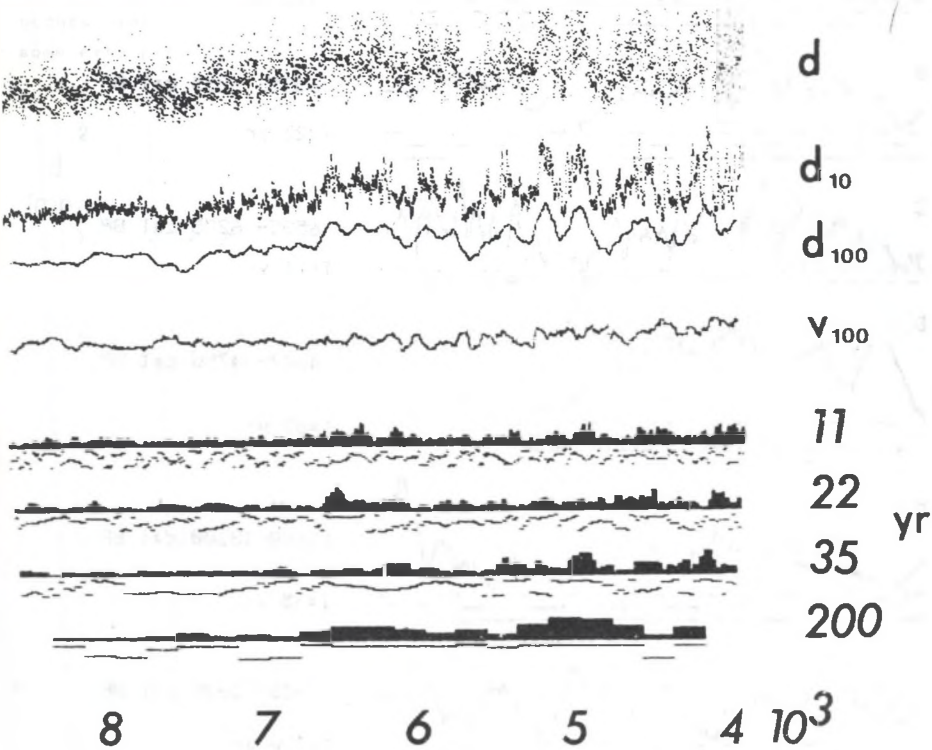


Fig. 1. The sequence of laminae thicknesses with results of running averaging (d - raw data; d_{10} and d_{100} - 10 yr and 100 yr running averages, respectively; $\bar{v}_{100}$ - 100 yr running average of the coefficient of variation) and results of running phase analysis performed for periods equal to 11, 22, 35 and 200 yr. Time scale is based on calibrated ^{14}C dates (after Goslar et al., 1989).

4. VERIFICATION OF THE PRESENCE OF PERIODICITY

Even the most refined statistical tests depend on the subjective scientist's knowledge. And only trivial problem can be objectively solved. The author is far from the conviction that the presence of periodicity in analysed series of laminae thicknesses is proved. So the pictures are offered to the reader instead of simple statement: "yes, there are cycles".

Making use of the value of phase obtained in the RPA method, the square wave is shown below each plot of data series in Fig. 2. It seems reasonable to expect that the periodicity (with the given period) should occur in a series if data are somewhat similar to the presumed wave. The



Rys. 1. Sekwencja grubości lamin wraz z wartościami średnich bieżących (d - grubości lamin; d_{10} i d_{100} - średnie bieżące 10- i 100-letnie; $\bar{v}_{100}$ - stuletnia średnia bieżąca współczynnika wariancji) oraz wyniki poszukiwania periodyczności o okresach 11, 22, 35 i 200 lat. Skala czasowa oparta jest na kalibrowanych datach ^{14}C (wg: Goslar et al., 1989).

plot of series of laminae thicknesses is smoothed by running averaging with the time constant about three times smaller than T. Such smoothing operates as low-pass filter. On the contrary, the human eye operates usually as high-pass filter. Both filters may result in the enhancement of purely subjective conviction about the presence of a periodicity. Simple statistical tests lead to more objective conclusions. The Student's "t" test was performed for every cycle of the wave represented by couple of upper and lower part. The question tested was whether the group of raw

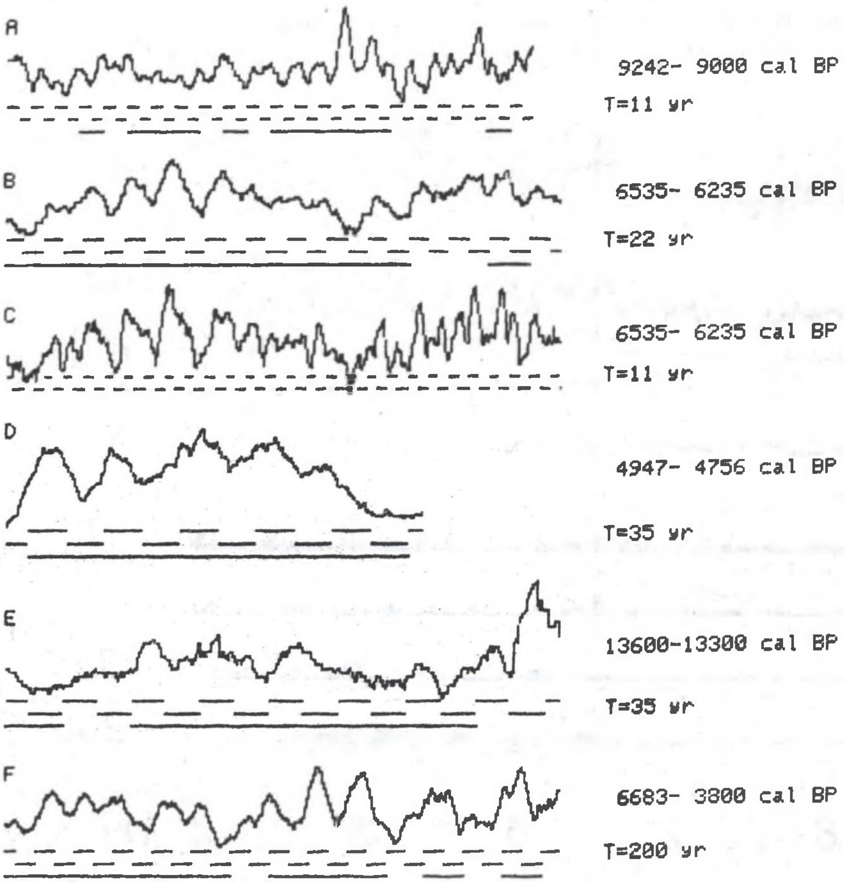


Fig. 2. Selected parts of laminae thicknesses series with periodic components.

Rys. 2. Wybrane fragmenty ciągu grubości lamin wykazujące obecność okresowości.

data (i.e. without running averaging) lying above the upper part of the wave is significantly higher than this lying above the lower part. The significance level of the test was chosen equal to 0.25. The cycles with the positive test results are underlined in Fig. 2. If more than half of the cycles are underlined than it is reasonable to expect the presence of real periodicity in the subseries (Walanus, 1989).

Selected illustrative examples are shown in Fig. 2, which presents fragments of sequence of laminae thicknesses which presumably contain some periodic components. The fragments were chosen mainly on the basis of Fig. 1, so they can not be regarded as randomly chosen. Because analysed series of data is long it may be suspected that every pattern may be found in it. However, the superposition of 11 yr and 22 yr cycles, which may be recognized in Fig. 2, is hardly of random origin. Also 200 yr cycle, which occurs over a quite long fragment of the series seems to be connected with some external causes.

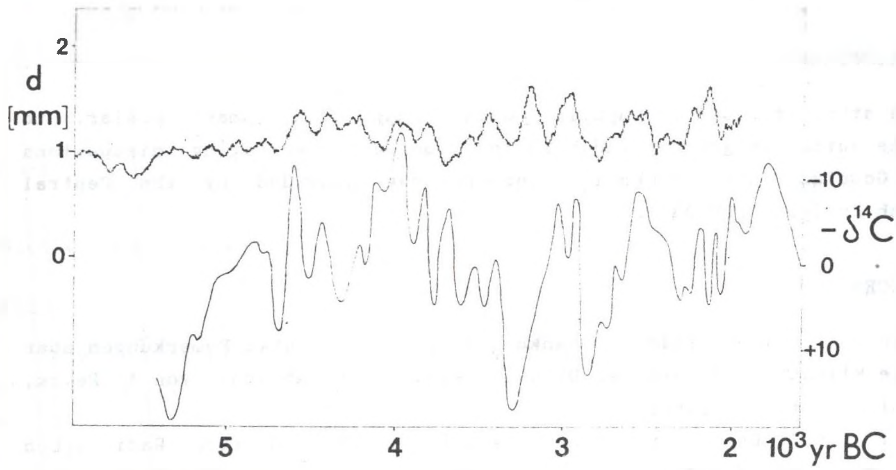


Fig. 3. Comparison of laminae thicknesses series with the smoothed ^{14}C data (after Neftel et al., 1981).

Rys. 3. Porównanie ciągu grubości lamin z wygładzonymi wartościami $\delta^{14}C$ (wg: Neftel et al., 1981)

In Fig. 3 the fluctuations of $\delta^{14}C$ are compared with changes of laminae thicknesses. The age scale and the values of $\delta^{14}C$ are taken from article by Neftel et al. (1981). It should be noted that in order to obtain better agreement with $\delta^{14}C$ the plot of thicknesses is shifted by 70 yr towards older ages. For the same reason the vertical scale of $\delta^{14}C$ is inversed (i.e. $-\delta^{14}C$ is plotted). May be Fig. 3 indicate negative correlation between sedimentation rate and concentration of ^{14}C in the atmosphere, so the situation would be similar to that found in sequences of tree rings widths (Sonnett, Suess, 1984).

5. CONCLUSIONS

When the more precise chronology of the sediment will be available any comparisons similar to those discussed above will become unequivocal. Concerning the question of the significance of periodicities revealed in this study it seems that the additional independent information would lead to a definite answer. It would be also of very high statistical weight to find coincidences of some periods appearing in the Gościąż sequence with those present in other records. Similarly, future analysis of data other than those resulting from measurements of laminae thicknesses will be highly important for verification of results obtained in this study.

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PERIODYCZNOŚCI W CIĄGU GRUBOŚCI LAMIN OSADÓW Z JEZIORA GOŚCIĄŻ

Streszczenie

Metodę bieżącej analizy fazowej zastosowano do poszukiwania występowania cykliczności w sekwencji grubości lamin rocznych osadów Jeziora Gościąż. Analizowana sekwencja obejmuje ok. 10,000 lamin rocznych w postaci siedmiu nieprzerwanych ciągów, rozdzielonych przerwami o nieznanej lub oszacowanej długości. Stwierdzono, że podstawowe charakterystyki statystyczne poszczególnych ciągów są praktycznie niezmienne w czasie. Poszukiwania cykliczności przeprowadzono dla kilku zadanych wartości okresu, wybranych na podstawie danych literaturowych. Użyte do analizy wartości okresu odpowiadają 11 i 22-letnim cyklom aktywności słonecznej, 35-letniemu cyklowi Brucknera oraz cyklowi 200-letniemu. Wyniki przeprowadzonej analizy wskazują istnienie poszukiwanych cykli w niektórych częściach badanej sekwencji. Problem wykazania statystycznej istotności wykrytych cykli wymaga jednak dalszych badań.

ЦИКЛИЧНОСТИ В ПОСЛЕДОВАТЕЛЬНОСТИ ТОЛЩИНЫ СЛОЕВ ОСАДКОВ ИЗ ОЗЕРА ГОСЦИОНЖ

Резюме

Метод последовательного фазового анализа применен для раскрытия цикличностей имеющих место в последовательности толщины годичных слоев осадков из озера Госционж. Анализ проведен для данных в интервале времени около 10 тыс. лет. Исследованная последовательность состоит из 7 непрерывных сегментов. Найдено, что основные статистические характеристики индивидуальных непрерывных фрагментов почти не изменяются. На основе литературных данных проведен анализ цикличностей для значений периодов равных 11 и 22 лет (солнечные циклы), 35 лет (цикл Брюкнера), и 200 лет. Полученные результаты достоверно доказывают присутствие этих циклов в некоторых участках рассматриваемой последовательности, однако для доказательства статистической истинности этих результатов нужны дальнейшие исследования.