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Historia jeziora Gorbacz

The history of Lake Gorbacz

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Abstract — The author studied the bed sediment of Lake Gorbacz (Białystok District and Province) with reference to its water, inactive chlorophyll, and organic matter contents. By comparing the findings with those of the palynological and plant remains on the peat bog of Gierasimow et al. (1957), the author made an attempt to reconstruct the history of the lake, which was probably formed as a result of the last glacial period.

Introduction

In recent years while carrying out research on the characteristics of various lakes and ponds, the author has endeavoured to establish the ecological conditions in the given lake or pond from the time of its formation to the present day. In this research the methods used in paleobotanical investigations were employed as well as those based on the remains of animal organisms (Frey 1958, Stahl 1959, Goulden 1964, 1966, Czeczuga et al. 1970).

Chemical methods are often used in which the quantitative changes in the commonest elements of the organic substances are analysed (Hutchinson, Wollack 1940, Livingstone, Boykin 1962, Mackereth 1966, Czeczuga, Gołębiewski 1966, 1969, Czeczuga et al. 1970).

Recently, in researches on the history of lakes and ponds, the method of quantitative changes in plant pigments such as inactive chlorophyll, carotenoids and others (Vallentyne 1955, Züllig 1956, Czeczuga 1959, 1965, 1969, 1969a, Czeczuga, Czerpak 1968) has been introduced.

An extremely interesting investigation has recently been made by

Wolfe (1966 a—c, 1967 a—c) on the history of certain African lakes in which the proportions of fungus spores were studied.

Some years ago pollen studies and studies of plant remains were carried out on the peat bog surrounding Lake Gorbacz (Gierasimow et al. 1957). The present author decided to determine the proportions of the organic matter and inactive chlorophyll in this lake in order to reconstruct its history on the basis of the above-mentioned indices.

Material and methods

The investigations were carried out on Lake Gorbacz, situated in the north-eastern region of Poland. It is situated in the centre of a peat hollow. The surface of the lake covers 19.8 hectares and its maximum depth is 1.2 m. Its greatest length is 426 m and its greatest width 394 m. It is a typical dystrophic type of lake.

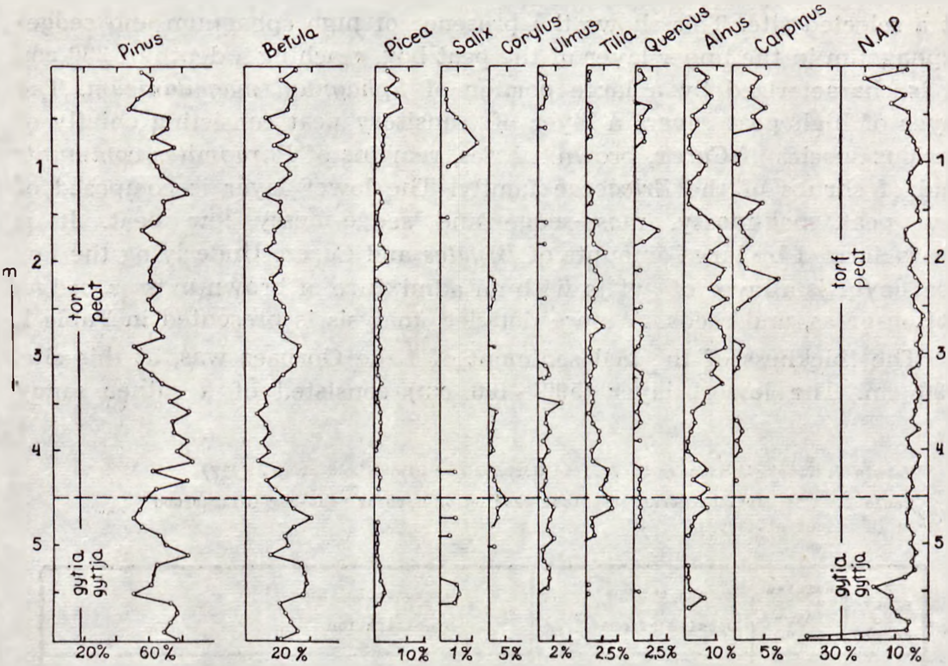
The investigations included pollen analysis, identification of remains of mosses (Gierasimow et al. 1957), and a study of the proportions of organic matter and chlorophyll in the bed sediments of the lake.

The boring of the bed sediments was carried out on March 20th, 1964, at a depth of 65 cm and also by means of a Hiller borer. Samples for analysis were collected at intervals of 5 cm but in order to obtain a more complete picture of the bed sediments at certain depths, samples were taken every 2.5 cm. The samples were placed in glass tubes and corked. They were then numbered and dipped in paraffin in order to preserve the water. The samples were kept in the dark at 4—6°C until the chlorophyll content was determined.

In the laboratory, the percentage of water in the sediment, the amount of inactive chlorophyll, and the percentage of organic material in relation to the dry mass of the bed sediments were determined with the minimum delay, following the method described in the author's previous papers (Czeczuga 1959, 1965, 1965a).

Results

The results of the pollen analysis of the peat-bog are given in fig. 1. As can be seen on the diagram, there are essentially two levels (Gierasimow et al. 1957). The lower level consisting of gyttja (600—450 cm) contains pine and birch tree pollen grains and the higher level, apart from the pollen types of the lower level, contains also pollen grains from a mixed forest. The pollen of deciduous trees and spruce forms on an average 10 to 15% of the total amount of pollen. An increase in the amount of spruce pollen was observed at a level of approximately 105 cm up to the surface of the present-day Gorbacz peat bog. Concerning the pollen



Ryc. 1. Diagram pyłkowy torfowiska Gorbacz (wg G i e r a s i m o w i inni 1957)
Fig. 1. Pollen diagram of Gorbacz peat bog (G i e r a s i m o w et al. 1957)

of herbaceous plants, a greater amount was observed in the lower layer (gyttja) and they are predominantly pollens of aquatic plants.

Fig. 2 presents the vertical stratigraphical section of Gorbacz peat-bog

Ryc. 2. Przekrój pionowy torfowiska Gorbacz (wg G i e r a s i m o w i inni 1957)
Fig. 2. Vertical stratigraphical section of Gorbacz peat bog (G i e r a s i m o w et al. 1957)

at a selected site. This shows the presence of high sphagnum and sedge--sphagnum in the upper layer of the peat bog, reaching a depth of 330 cm. It is characterized by a large portion of *Sphagnum magellanicum*. The layer of high peat covers a layer of transitory peat consisting chiefly of various species of *Carex*, brown mosses, remains of *Phragmites communis* and of shrubs of the *Ericaceae* family. The lower layer is composed of low peat, bog-mossy, moss-sedge and sedge-mossy low peat. It is characterized by large amounts of *Bryales* and *Carex*. Underlying the low peat layer is a layer of gyttja with an admixture of brown mosses, sedge, cotton-grass, and reeds. A more detailed analysis is presented in Table I.

The thickness of the bed sediment of Lake Gorbacz was, at this site, 590 cm. The lowest layer (590—490 cm) consisted of a rather sandy

Tabela I. Przekrój pionowy torfowiska Gorbacz (wg Gierasimow et al. 1957)

Table I. The vertical stratigraphical section of Gorbacz peat-bog (Gierasimow et al. 1957)

Nr próby No sample	Warstwa w cm Layer in cm	Rodzaj torfu Species of peat	Wyszczególnienie Specification
1.	surface - 20	sfagnowy sphagnum	Sphagnum 68% (Sph. magellanicum 54%); Ericaceae 13%, Eriophorum vaginatum 10%.
2.	20- 50	"	Sphagnum 66% (Sph. rubellum 59%), Ericaceae 15%.
3.	50- 80	"	Sphagnum 94% (Sph. rubellum 89%).
4.	80-110	"	Sphagnum 83% (Sph. recurvum 75%), Eriophorum vaginatum 14%.
5.	110-140	"	Sphagnum 67% (Sph. magellanicum 52%), Eriophorum vaginatum 26%.
6.	140-170	wełniankowo-sfagnowy sedge-sphagnum	Sphagnum 69% (Sph. rubellum 34%, Sph. magellanicum 22%), Eriophorum vaginatum 27%.
7.	170-190	sfagnowy sphagnum	Sphagnum 81% (Sph. rubellum 44%, Sph. magellanicum 19%), Eriophorum vaginatum 13%.
8.	190-210	"	Sphagnum 70% (Sph. magellanicum, Sph. angustifolium 23%), Eriophorum vaginatum 19%.
9.	210-240	"	Sphagnum 81% (Sph. magellanicum 54%, Sph. angustifolium 16%), Ericaceae 10%.
10.	240-270	wełniankowo-sfagnowy sedge-sphagnum	Sphagnum 69% (Sph. magellanicum 34%, Sph. angustifolium 22%), Eriophorum vaginatum 21%.
11.	270-300	"	Sphagnum 47% (Sph. magellanicum 32%), Eriophorum vaginatum 38%, Ericaceae 13%.
12.	300-330	"	Sphagnum 47% (Sph. magellanicum 14%, Sph. rubellum 11%), Eriophorum vaginatum 34%, Ericaceae 16%.
13.	330-360	bagnicowo-turzycowy bog-sedge	Carex 42% (C. rostrata 17%, C. filiformis 11%) Scheuchzeria palustris 27%, Bryales 17%, Phragmites communis 2%.
14.	360-390	bagnicowo-mszysty bog-mossy	Bryales 41%, Scheuchzeria palustris 23%, Carex 22% (C. rostrata 11%, C. filiformis 10%), Phragmites communis 2%.
15.	390-420	mszysto-turzycowy moss-sedge	Carex 33% (C. filiformis 15%), Bryales 25%, Scheuchzeria palustris 20%, Sphagnum 7%, Phragmites communis 3%.
16.	420-450	wełniankowo-mszysty sedge-mossy	Bryales 50%, Carex 21%, Scheuchzeria palustris 17%, Sphagnum 2%.
17.	450-480	gytia gyttja	gyttja 33%, parts of plants 67% (Carex 49%, Bryales 5%, Sphagnum 5%).
18.	480-510	"	gyttja 34%, parts of plants 66% (Sphagnum 24%, Bryales 23%, Eriophorum 21%, Carex 18%).
19.	510-540	"	gyttja 55%, parts of plants 45% (Eriophorum 18%, Sphagnum 16%, Phragmites communis 12%, Carex 11%, parts of animals 20%.

deposit, the last samples even containing an admixture of small stones. In this layer, at a depth of 530—520 cm, the sediment was brown in colour. The upper layer, which stretches from 490 cm up to the present bed, contained less sand and was rather of the peat type as regards the colour of the sediment, a thin layer at a depth of 425—420 cm was greenish-yellow, whereas from a depth of approximately 380 cm the sediment was lighter in colour, after which it became dark-grey, light--brown and, at 165 cm, dark-brown.

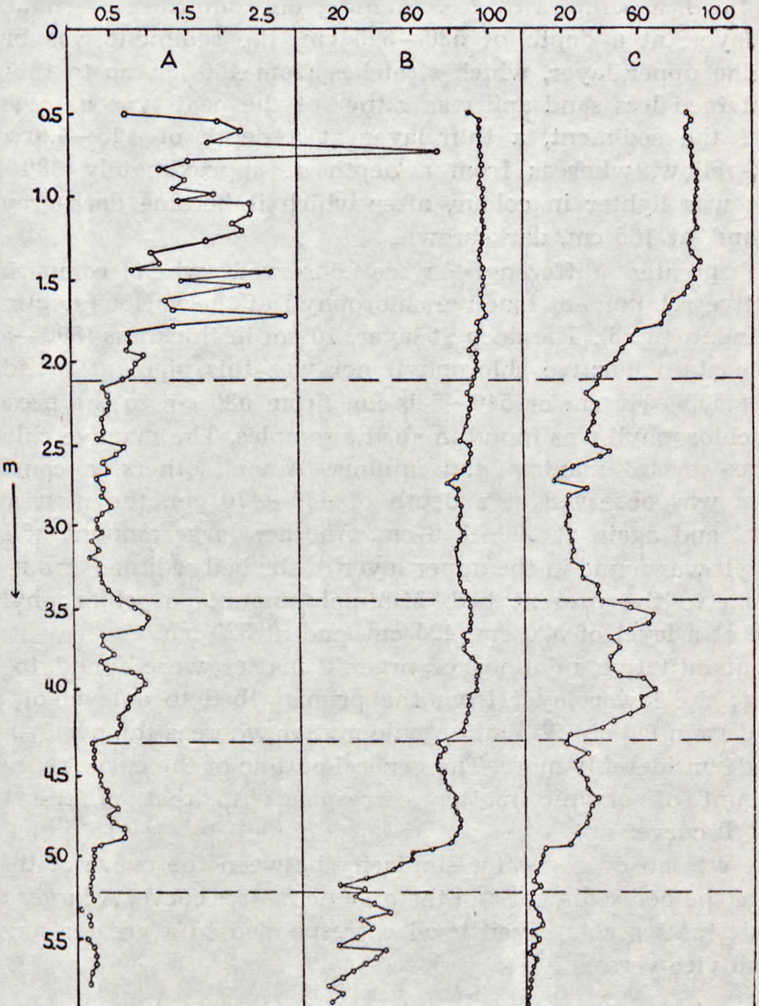
Much greater differences were observed when comparing the quantitative relations of inactive chlorophyll at the various depths of the bed sediment (fig. 3). The deepest layer, 10 cm in thickness (590—580 cm), did not contain inactive chlorophyll nor was this pigment found at the depths of 555—545 cm or 540—530 cm. From 530 cm to the present bed inactive chlorophyll was found in all the samples. The inactive chlorophyll curve has several maxima and minima. Among others, a considerable maximum was observed at a depth of 480—470 cm, the next at 400—390 cm, and again at 360—350 cm. Another large amount of inactive chlorophyll was found in the upper layer of the bed sediment from a depth of 175 cm to the present bed. Minimal amounts of chlorophyll were observed at a level of 520 cm, 425 cm, and at 320 cm.

The quantitative relations of organic matter were found to be the following; the lower layer from the primary bed to a level of 495 cm contained from 0.34 to 9.1% of organic matter whereas the overlying layer contained considerably more. The general outline of the curve representing the amount of organic matter corresponds to that of the inactive chlorophyll curve.

There was an even greater similarity between the curve of the water content of the bed sediment and the organic matter curve. A larger amount of organic matter at a given level corresponded to a greater amount of water and vice versa.

Discussion

In all probability, Lake Gorbacz arose as a result of the last glacial period. On the basis of a quantitative analysis of inactive chlorophyll and organic matter it would seem that in the early phase of its development the lake, which had a poor organic production, changed slowly into a more productive one. The lack of inactive chlorophyll at depths of 555—530 cm indicates a complete shallowing of the lake at this site. The author noted a similar type of change in Lake Kolno, which like Lake Gorbacz, lies in marshy lowland in an area previously forested. ^{14}C assays of the absolute age of Lake Kolno sediment revealed that these types of sediments were deposited before the Atlantic period, probably during the Boreal. K o r d e reported the drying up of some lakes during the Boreal period (1960).



Ryc. 3. Zawartość chlorofilu nieaktywnego (A w mg/g suchego osadu dennego), wody (B w %) i substancji organicznej (C w %) w osadzie dennym jeziora Gorbacz

Fig. 3. The quantitative relations of sedimentary chlorophyll (A in mg/g of dry sediment), absolute water (B in %) and organic matter content (C in %) of the Lake Gorbacz bed sediment.

Perhaps the lack of chlorophyll at a depth of 555—530 cm is connected with buried ice (G r o s s 1937). When this ice melted, the earth covered by the ice was flooded and thus became the bottom of a lake forming there, gradually becoming covered with sediment. If such was the case, this layer would belong to the Alleröd interphase period (G a r u n k š t i s 1958, G u d e l i s, K a b a i l e n e 1958, S e i b u i t s 1961).

At a depth of about 525 cm a sudden fall in inactive chlorophyll and organic matter occurred, after which a maximum was noted at approximately 480 cm. Another fall in these indices was then observed down to 435 cm. This layer of sediment was formed during the Atlantic period. From the example of Lake Gorbacz it can be seen that the Atlantic period may be divided into three sub-periods: the first and last with poor organic matter production and the second considerably greater. The author has observed a similar phenomenon in Lake Kolno (Czeczuga, Gołębiewski 1966). Korde (1960) also made similar observations in many lakes of the European part of the Soviet Union. By means of the ^{14}C method, it was found in the investigations on Lake Kolno that the increase in production of this period occurred in 6.526 $\pm$ 330 B.P. years.

During the Atlantic period, greater amounts of inactive chlorophyll and organic matter (at a level of 420—435 cm) were deposited. This layer is divided by a characteristic minimum indicating the influence of the sub-boreal period with a dry climate. Such changes have been observed in other lakes of this region (Czeczuga 1959, 1965, 1965 a, 1968, Czeczuga, Gołębiewski, 1966, 1969). The determinations made by the ^{14}C method on huge trunks of alder from the peat bog of the River Narew revealed that the period of a warmer climate occurred 3.800 $\pm$ 70 B.P. years ago (Czeczuga 1968, 1969). Neyshtadt (1963) estimated the age of some sediments from this period, on the basis of the investigations on the peat-bed of Szuwałowski, to be approximately the same.

After this period there was no significant fall (except at depth 270 cm) in the amount of organic substances in the sediment and a sediment of peat type was formed. This was corroborated by the pollen analysis of the adjacent peat bog which, at this site had its beginnings in the sub-Atlantic period (Gierasimow et al. 1957).

The processes of peat formation, which began during the sub-boreal period, were subordinate to irreversible conditions governing this lake and many other lakes of North-East Poland (Stasiak 1965, Maksimow 1965). At the site where the samples were taken, low peat was deposited first, changing, as the surface of the lake decreased, to the transitional peat and in the final phase to high peat.

Of particular importance in the formation of the transitional peat bed over the low peat is the decrease in the amount of calcium compounds in the water of the low peat bed which precedes the formation of the transitional peat. This was confirmed by the results of investigations on the Gorbacz peat bog (Baszyński et al. 1956). The gyttja under the low peat is calcareous and grey-white in colour. Whereas at a level of 450—300 cm the CaO content formed 1.75% of the dry mass of the peat, at 150 cm it contributed only 0.73%. Similarly, our investigations at Lake

Kolno showed that from the sub-boreal period onwards, the calcium compounds steadily diminished (C z e c z u g a, G o ł ę b i e w s k i 1966).

Moreover, after taking more than o thousand borings, the authors found that the Lake Gorbacz of today was once part of an open-water complex with several branches, one of which covers the present-day bog and Lake Gorbacz, and another the bog and Lake Wiejki. The river Suprasl now flows from this ancient complex and the present-day peat bog (Topolany Bog). As a result of the gradual overgrowth of this complex, a low peat bed was formed over it while in the north-western part it is covered with high peat. The formation of high peat deposits over the low indicates that, in the history of its development, hydrological changes, namely the stopping of the flow of water to the north, occurred and the water then flowed from the lake and partly from the adjacent peat bog to the south-east to the peat bog of Imszar, the source of the rivulet Rudnik which empties into the river Narew. As a result, part of the low peat bog was on the watershed line and was watered only by rain water, deficient in nutritional elements. Consequently deposits of high peat were laid down.

It should here be mentioned that B a s z y ń s k i et al. (1954) found layers of pine in sections of a high peat bog at depths of 40, 130, and 290 cm, thus indicating that the peat bog had been overgrown by pine forest three times. The pine forest was destroyed at intervals by flooding during which the water moss *Sphagnum cuspidatum* E h r. grew. The overgrowth of the peat bogs by pine occurred during periods of reduced humidity, whereas the formation of deposits of *Sphagnum cuspidatum* E h r. occurred during floods, i.e. in a period of increased humidity. This corroborates our observations, based on the bed sediments of a number of lakes, which have shown that after the sub-boreal period there were periods of a dryer climate (C z e c z u g a 1959, 1965, 1965a).

On the diagram illustrating the quantitative relations of inactive chlorophyll and organic matter the sub-atlantic period is marked from a level of 335 cm to 215 cm. From a depth of approximately 2 m the so-called neoboreal period begins. On this diagram the neoboreal period is not separated from the historical period as in our previous investigations on the lake sediments of the post-glacial period (C z e c z u g a 1959, 1965, 1965a).

STRESZCZENIE

Autor porównał wyniki badań nad stosunkami ilościowymi chlorofilu nieaktywnego, substancji organicznej i zawartości wody w osadzie dennym jeziora Gorbacz z wynikami badań pyłkowych i strukturalnych torfowiska otaczającego to jezioro, przeprowadzonych swego czasu przez G i e r a s i m o w i innych (1957).

Według wszelkiego prawdopodobieństwa jezioro Gorbacz powstało w wyniku ostatniego zlodowacenia. Przeprowadzone badania wykazały, że w początkowej fazie

swego rozwoju jezioro o ubogiej produkcji organicznej przekształcało się powoli w zbiornik bardziej produktywny. Stwierdzona nieobecność chlorofilu nieaktywnego na głębokości 5,55—5,30 m wskazywałaby albo na zupełne wypłycenie jeziora na tym stanowisku, bądź to wiąże się ze zjawiskiem zagrzebanych martwych lodów. W każdym bądź razie miało to miejsce przed okresem atlantyckim, co zostało stwierdzone metodą ^{14}C dla jeziora Kolno, w którym to obserwowano podobne zjawisko. Po okresie atlantyckim w jeziorze Gorbacz odkładał się osad typu torfiastego. Potwierdzeniem tego jest analiza pyłkowa torfowiska przylegającego do jeziora Gorbacz. Zapoczątkowane procesy torfotwórcze w okresie subborealnym w warunkach tego jeziora były już nieodwracalne, tak jak zresztą dla wielu innych jezior północno-wschodniej części Polski.

REFERENCES

Baszyński T., E. Kłyszejko, W. Sławiński, I. Zawadzka, K. Zawadzki, 1954. Torfowisko Wysokie Gorbacz. Część I. Badania botaniczne, stratygraficzne i analiza chemiczna gytii. Acta Soc. Bot. Pol., 33, 663—676.

Baszyński T., W. Sławiński, I. Zawadzka, K. Zawadzki, 1956. Torfowisko Wysokie Gorbacz. Część II. Badania chemiczne i biochemiczne. Acta Soc. Bot. Pol., 35, 421—433.

Czeczuga B., 1959. Zawartość chlorofilu w osadach dennych jezior Rajgrodzkich w okresie polodowcowym. Polskie Arch. Hydrobiol., 6, 155—172.

Czeczuga B. 1965. The application of the Blytt and Sernander classification to the post-glacial sediment stratification in the lake of the north-eastern region of Poland. Hydrobiologia, 26, 527—538.

Czeczuga B., 1965a. Quantitative changes in sedimentary chlorophyll in the bed sediment of the Mikołajki lake during the post-glacial period. Schweiz. Zeitschr. Hydrolog., 27, 88—98.

Czeczuga B., 1969. The history of some lakes in the north-eastern region of Poland, based on chemical investigations of the sediments. Mitt. Internat. Ver. Limnol. 17, 351—355.

Czeczuga B., 1969a. A few comments on the history of the valley of the river Narew. Schweiz. Zeitschr. Hydrolog., 31, 157—161.

Czeczuga B., R. Czerpak, 1968. Investigations on vegetable pigments in post-glacial bed sediments of lakes. Schweiz. Zeitschr. Hydrolog., 30, 217—231.

Czeczuga B., Z. Gołębiewski, 1966. History of Kolno lake as revealed by the bed sediments. Schweiz. Zeitschr. Hydrolog., 28, 173—183.

Czeczuga B., Z. Gołębiewski, 1969. Chemical studies of the bed sediment of lake Kruklin. Acta Hydrobiol., 11, 261—272.

Czeczuga B., Z. Gołębiewski, W. Kossacka, 1970. The history of lake Wiżajny in the light of chemical investigations of the sediment and *Cladocera* fossilis. Schweiz. Zeitschr. Hydrolog., 32, 115—125.

Frey D. Y., 1958. The late-glacial cladoceran fauna of a small lake. Arch. Hydrobiol., 54, 209—275.

Garunkštis A., 1958. K woprosu o klasifikacji oziernych osadkow izwiestnych w oziorach Litowskoj SSR. Naučn. Sob. Inst. Geol. i Geogr. Akad. Nauk Lit. SSR, 6.

Gierasimow M., A. Kościk, Z. Wojtowicz, 1957. Torfowisko Wysokie Gorbacz. III-Badania stratygraficzne, palinologiczne i fizyczne. Acta Soc. Bot. Pol., 26, 675—699.

Goulden C. E., 1964. The history of the *Cladocera* Fauna of esthwaite water (England) and its limnological significance. Arch. Hydrobiol., 60, 1—52.

Goulden C. E., 1966. La Aguada de Santa Ana Vieja: An interpretative study of the cladoceran microfossils. Arch. Hydrobiol., 62, 373—404.

Gross H., 1937. Nachweis der Allerödschwankung im süd- und ostbaltischen Gebiete. Beih. z. Bot. Zbl. ser. B 57.

Gudelis W., M. Kabailene, 1958. Allerödskij i doallerödskij pieriody w Litvie v swietle palinołogičeskich issledovanij otłoženij bołota Nopaino. Trudy Inst. Geol. i Geogr. Akad. Nauk Lit. SSR, 6.

Hutchinson G. E., A. Wollack, 1940. Studies on Connecticut lake sediments. II-Chemical analyses of a core from Linsley Pond, North Branford. Am. J. Sci., 238, 493—517.

Korde N. W., Biostratifikacja i tipołogia ruskich sapropielej. Moskva 345 pp. Izd. Akad. Nauk SSSR.

Livingstone D. A., J. C. Boykin, 1962. Vertical distribution of phosphorus in Linsley pond mud. Limnol. and Oceanogr., 7, 57—62.

Mackereth F. J. H., 1966. Some chemical observations on post-glacial lake sediments. Philosoph. Trans. Roy. Soc. London, B250, 165—213.

Maksimow A., 1965. Torf i jego użytkowanie w rolnictwie. Państw. Wyd. Roln. i Leśne, Warszawa.

Neyshtadt N. J., 1963. Sapropel deposits in USSR. Intern. peat Congr., 1—18.

Seibuits A., 1961. O stratigrafičeskom značenii dwuchsłojnych torfianistych podsapropielewych obrazowanij. Trudy A. N. Lit. SSR, ser. B, 3, 30.

Stahl J. B., 1959. The developmental history of the chironomid and chaoboris faunas of Myers Lake. Invest. Indiana Lakes and Streams, 5, 47—102.

Stasiak J., 1965. Badania nad starożytnym krajobrazem Pojezierza Suwalskiego w rejonie Szwajcarii. Prace Białostockiego Towarzystwa Naukowego, 7, 5—42.

Vallentyne J. R., 1955. Sedimentary chlorophyll determination as paleobotanical method. Canad. J. Bot., 33, 304—313.

Wolfe F. A., 1966a. Fungus spores in East African lake sediments. Bull. Terrey. Bot. Club, 93, 104—113.

Wolfe F. A., 1966b. Fungus spores in East African lake sediments II. Jour. Elisha Mitchell Sci. Soc., 82, 57—61.

Wolfe F. A., 1966c. Fungus spores in East African lake sediments III. Jour. Elisha Mitchell Sci. Soc., 82, 149—154.

Wolfe F. A., 1967a. Fungus spores in East African lake sediments IV. Bull. Torrey Bot. Club, 94, 31—34.

Wolfe F. A., 1967b. Fungus spores in East African lake sediments V. Mycologia, 59, 397—404.

Wolfe F. A., 1967c. Fungus spores in East African lake sediments. VI. Jour. Elisha Mitchell. Sci. Soc., 83, 113—117.

Züllig H., 1956. Sedimente als Ausdruck des Zustandes eines Gewässers. Mem. Ist. Ital. Idrobiol. Suppl. 8, 485—530.

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