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THE STRATIGRAPHIC POSITION OF BRACKISH-WATER BOTTOM SEDIMENTS FROM THE LAKE ŻARNOWIEC (N POLAND)

Pozycja stratygraficzna bıachicznych osadów dennych Jeziora Żarnowieckiego

ABSTRACT. A mesohalobus diatom flora characteristic of so-called „clypeus lagoons" was found in the sediments of the northern part of Lake Żarnowiec. The formation of a shallow body of brackish water was linked with the Subboreal phase of the Littorine transgression of the southern Baltic Sea.

INTRODUCTION

This paper will deal with the upper layers of a bottom sediment profile taken from the northern part of Lake Żarnowiec. Palynological analysis of these layers revealed the presence in the samples from depths 123 and 120 cm of a rich diatom flora comprising mainly the mesohalobous species *Campylodiscus clypeus* Ehr. It was this fact which stimulated a detailed stratigraphic examination of this section of the core.

Papers on the history of Lake Żarnowiec are few. They include older work such as the papers by Sonntag (1912) and Zaborski (1933), and newer studies by Rosa (1963) and Roszkówna (1964). Other authors tackling this problem reached similar conclusions or referred to the above-mentioned publications. All of these papers treat the problem from the geomorphological point of view.

The palaeobotanical material presented in this article are part of a broader investigation into the post-glacial history of the vegetation in the Lake Żarnowiec area (Latałowa 1982a, b). The results of these studies made it possible to reproduce the changes in ecological conditions during the development of this lake in the Late Glacial and Holocene. The present paper supplements the previous ones with information on the development of the northern part of Lake Żarnowiec during the Subboreal period.

LOCALIZATION, DESCRIPTION OF THE PROFILE, METHODS

Lake Żarnowiec lies in the eastern part of the Żarnowiec Upland and is about 4 km distant from the sea-shore (Fig. 1). The river Piaśnica flows through the lake. The study material was taken from a spot where the water is about 2 m deep, in the northern, shallowest part of the lake. The entire profile was obtained using a Boros sampler, only the unconsolidated, topmost sediment was taken by inserting a 5 cm diameter PCV tube into the lake bottom directly from the boat (Latałowa 1982a, b).

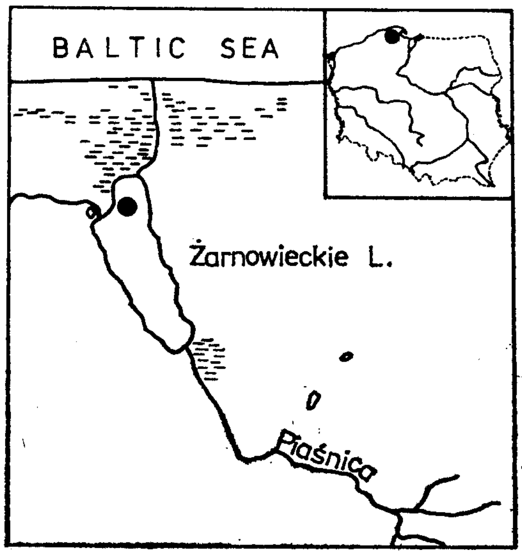

Fig. 1. Map of the study area. The dot indicates the spot from which the profile was taken

The layers in the upper part of the profile were as follows:

Layer No	Depth (cm)	Description of sediment
1	36—45	Grey-brown sand with shells and plant detritus
2	45—52	Brown detritus gyttja with shells and admixture of sand
3	52—57	Dark brown detritus gyttja with traces of sand and single shell fragments
4	57—118	Dark grey calcareous gyttja with varying admixtures of finely-divided plant detritus, shell fragments and trace quantities of silt
5	118—125	Dark brown calcareous detritus gyttja, with an admixture of shells

The samples for pollen analysis were pre-treated with 10 % HCl to remove calcium carbonate, then acetolysed by Erdtmann's method. The percentage content of sporomorphs was calculated from the sum AP + NAP. AP included shrub pollen, though spores and pollen from aquatic and marsh plants were excluded from NAP. The results of this analysis are set out in a percentage diagram (Fig. 2). The results of plant macrofossil analysis are shown as a curve of the absolute numbers of identified seeds and fruits contained in 100 cm^3 of sediment.

The sediment samples for diatom analysis were treated with 10 % HCl, then boiled in H_2O_2. The diatoms were separated from these samples by flotation in cadmium liquid of specific gravity 2.5. Microscope slides were prepared by melting the material in Pleurax. About 1000 diatom specimens were counted in each sample; in two samples (from depths 123 and 120 cm) this number was reduced to 500 because of the small number of diatoms found in them. The percentage participation of each species was then calculated. Fig. 3 illustrates the percentages (above 1 %) of selected diatom species at given depths.

The diatom flora was divided into halobous groups in accordance with Kolbe's classification (1927). The percentages of these groups are shown in Fig. 4.

The diatoms were classified as belonging to the plankton or the periphyton. A number of papers were useful here, including those by Hustedt (1930—1966), Siemińska (1964), Cholnoky (1968) and Przybyłowska-Lange (1979) (Fig. 5).

The diatoms were divided into ecological groups with respect to their pH requirements in accordance with Hustedt's sugestions (1939) (Fig. 6).

THE RESULTS OF POLLEN ANALYSIS

The profile examined (Fig. 2) was deposited during the Early Subboreal period. This fact may be gleaned by comparing the radiocarbon-dated diagrams from the peat-bog near Lake Żarnowiec and the peat bog in the Darżlubie Forest (Latałowa 1982a, b). This fragment shows all the features of the *Corylus-Quercus* pollen assemblage zone described on the basis of the profiles mentioned earlier. As is typical of the study area, this zone is characterized by high percentages of *Quercus* and *Corylus* pollen and minimal values of *Pinus*. The *Tilia* and *Ulmus* curves do not yet show a definite fall. *Carpinus* and *Fagus* are represented by single pollen grains. The pollen of *Plantago lanceolata* and *Cerealia* occur sporadically too. *Urtica* and *Rumex* t. *acetosa/acetosella* do occur in rather larger quantities, but we have not yet got the picture typical of more advanced human settlement. There is a clear hiatus in the upper part of the profile — only the pollen spectra of samples from depths 45, 40 and 37 cm represent the Subatlantic period. The presence of pre-Quaternary sporomorphs in these samples would suggest that intensive erosion was in progress in the neighbourhood of the lake. The lack of sediments from the younger Subboreal period and from almost the whole Subatlantic period indicates that they were being continually washed away by the river Piaśnica.

The particularly large percentage values of *Alnus* pollen are a local feature and are undoubtedly connected with the periodic waterlogging of the lakeside areas resulting from changes in sea level during the Subboreal period.

The vegetational changes taking place in the vicinity of the lake and in its littoral zone are also expressed in the pollen curves of aquatic plants, and further, by the curves of other microfossils such as *Pediastrum boryanum* and the hairs of *Ceratophyllum* sp., given at the end of the pollen diagram (Fig. 2). More pollen from reed-swamp plants was found in the upper and lower parts of the profile than in its central section. The high percentage values of *Pediastrum boryanum* indicate that water flow through the lake during the whole period under discussion was not intensive.

Single pollen grains from *Plantago* cf. *coronopus*, a species characteristic of brackish meadow communities, were noted in samples 120 and 110.

THE RESULTS OF PLANT MACROFOSSIL ANALYSIS

Considerable quantities of plant macrofossils though from a small number of species (Fig. 2) make up the picture of this section of the Lake Żarnowiec bottom sediment profile. Absolutely predominant in the profile are *Characeae* oospores and the fruits of *Najas marina*. Other species are represented by single specimens. On the basis of these plant fragments, three Macrofossil Assemblage Sub-Zones can be distinguished within the *Characeae-Najas marina* MAZ-JZ V (cf. Latałowa 1982).

The *Najas marina* MASZ—JZ Va (125—100 cm) is characterized by large numbers of *Najas marina* fruits (max. 30) and a relatively low number of *Characeae* oospores (max. 839). They are accompanied by single *Schoenoplectus lacustris* nuts and *Potamogeton natans* stones. This data indicates the existence of macrophyte communities typical of shallow waters.

The sediment layer at 100—55 cm was almost entirely the domain of *Characeae* oospores, of which there were from 245 to 1772 per 100 cm^3 of sediment (MASZ—JZ Vb — *Characeae*). This resulted from a periodic rise in the lake's water level.

The reappearance of *Najas marina* fruits (max. 42), accompanied by *Schoenoplectus lacustris* nuts and also *Zannichellia* cf. *palustris*, *Ceratophyllum* cf. *demersum* and *Potamogeton* sp. (MASZ—JZ Vc — *Characeae—Najas marina—Schoenoplectus lacustris*), suggests the presence of a *Parvopotamogetono-Zannichellietum* macrophyte community, typical of shallow waters rich in calcium carbonate (Podbielkowski & Tomaszewicz 1979).

THE ECOLOGICAL CHARACTERISTICS OF THE DIATOM FLORA

168 species of diatoms were identified in the Subboreal sediments of the northern part of Lake Żarnowiec. They included 122 indifferent oligohalobous species, 23 mesohalobous (brackish water) species and 16 halophilous oligohalobous species.

Of the remaining halobous groups, i.e. typically marine-euhalobous diatoms and diatoms existing only in fresh water, in other words halophobous oligohalobous diatoms, there were few — 3 of the former and 4 of the latter species. Most of the species are widely distributed, occurring at present in the shore zones of inland fresh-water lakes and ponds. The diatom frustules found in the sediments were well preserved, which indicates that their sedimentation took place in calm waters.

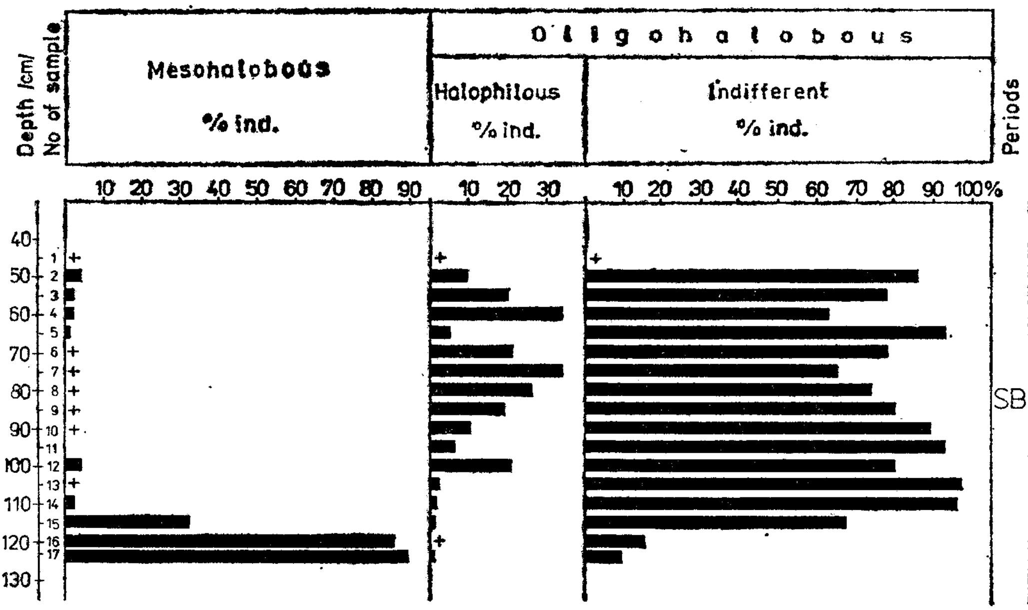

Fig. 4. Percentage distribution of halobous groups of diatoms

The results of diatom analysis of the sediments in the lower part of the examined core, formed at the beginning of the Subboreal period, point to the slight salinity of the waters in the lake. Mesohalobous diatoms were present at depths 123, 120 and 115 cm in the core, and comprised from 90.6% to 33.1% of the total number of frustules in the sample (Fig. 4). *Campylodiscus clypeus* (87—71%) was the dominant species between 123 and 120 cm, whereas the commonest diatom at 115 cm (about 22%) was *Anomoeonei. sphaeroph.ra* var. *sculpta* (Ehr.) O. Müll. (Fig. 3). Also of importance here were *Amphora commutata* Grun. and *A. holsatica* Hust. The euhalobous diatoms were represented by single frustules of *Actinocyclus ehrenbergii* Ralfs., *Grammatophora oceanica* (Ehr.) Grun., *Cocconeis scutellum* Ehr. and *Thalassiosira subtilis* (Østf.) Grun. The above-mentioned group of mesohalobous diatoms made it possible to distinguish the *Campylodiscus clypeus—Anomoeoneis sphaerophora* v. *sculpta* diatom assemblage zone DAZ—JZ 1 (cf. Latałowa 1982b).

The expansion of large numbers of mesohalobous diatoms of the genus *Campylodiscus*, especially *C. clypeus* and *Anomoeoneis sphaerophora*, is typical of shallow, brackish-water bay habitats, which Alhonen (1971) called „clypeus laggons". The very few euhalobous diatoms characteristic of the pelagic zone and particularly the total lack of *Coscinodiscus* species suggests that the salinity of the water in the northern part of the lake was low.

The species composition and the percentages of the halobous diatoms in the overlying samples indicate that the water was becoming less saline. The number of mesohalobous diatoms declines sharply (Fig. 3), and the dominant group are now the oligohalobous species, mostly the indifferent oligohalobous ones. At first

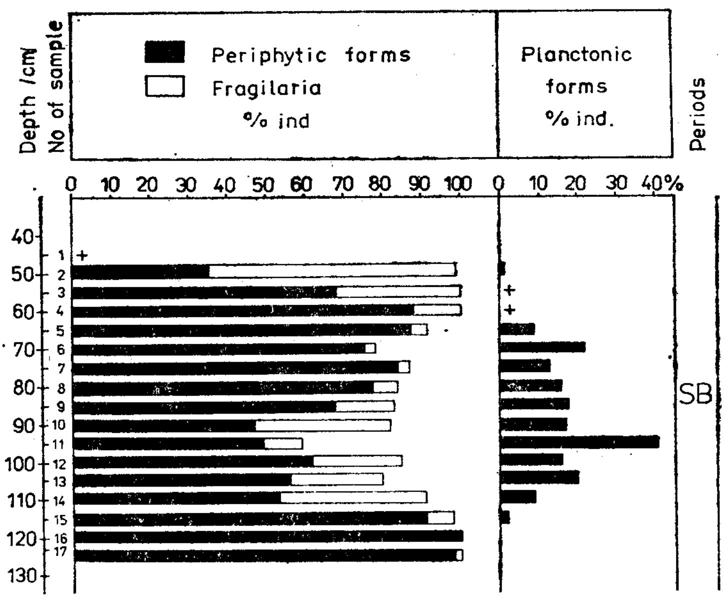

Fig. 5. Habitat groups of diatoms, classified as plankton or periphyton

there are more alkaliphilous species from among the littoral-zone vegetation (Figs. 5, 6), such as *Amphora ovalis* Kütz., with its variant *A. ovalis* var. *pediculus* Kütz., *Achnanthes lanceolata* (Bréb.) Grun. and *Fragilaria* species (Fig. 3). This layer corresponds to the *Fragilaria-Achnanthes* DAZ—JZ 2, distinguished by Latałowa (1982b).

In the centre of the examined core, plankton species (Fig. 5) from the genus *Cyclotella* and *Stephanodiscus astraea* (Ehr.) Grun. become more numerous (Fig. 3). This increase in numbers suggests a rise in the water level of the lake. The pH of the water also changed at this time, because there was increase in the numbers of species indifferent to the pH, that is, species which exist in water whose pH is roughly 7 (Fig. 6). The most common species here are *Cyclotella comta* var. *radiosa* Ehr., *Navicula pupula* Kütz. and *Cymbella ventricosa* Kütz. (Fig. 3).

A slight lowering of the lake's water level could have induced the development of littoral-zone halophilous species of the genus *Epithemia*, in particular *Epithemia sorex* Kütz. In the indifferent oligohalobous group, *Cymbella affinis* Kütz, *Epithemia intermedia* Fricke, *Gomphonema intricatum* var. *productum* Grun. (Fig. 3) were also of importance. This part of the core has been classified as the *Stephanodiscus astraea—Epithemia sorex* DAZ—JZ 3 (Latałowa 1982b).

As the northern part of the lake is becoming ever shallower, a benthic alkaliphilous flora is developing, *Amphora ovalis* var. *pediculus* and *Achnanthes clevei* Grun. being the most common. Alkalibiontic littoral-zone species such as *Epithemia turgida* (Ehr.) Kütz., and its variant *E. turgida* var. *granulata* (Ehr.) Kütz. are also found. Also increasing in numbers are alkaliphilous species of the genus *Achnanthes* (*A.*

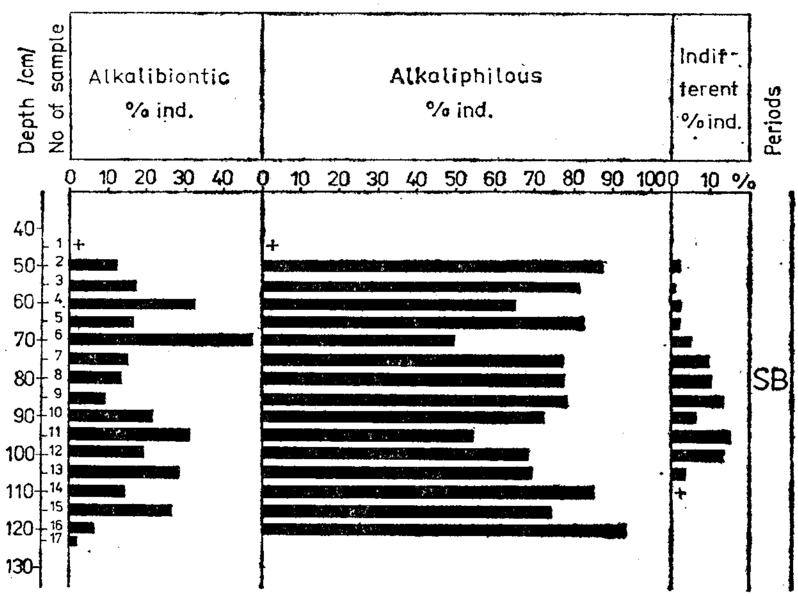

Fig. 6. Ecological distribution of diatom groups with respect to their water pH requirements

lanceolata var. *elliptica* Cl., *A. lanceolata* var. *rostrata* Schulz.), *Cocconeis placentula* var. *euglypta* (Ehr.) Cl., *Cymbella affinis* Kütz., *Cymbella lanceolata* (Ehr.) V. H. and numerous *Fragilaria* species (Fig. 3). The dominant *Fragilaria* species in the upper part of the core were *F. brevistriata* Grun., *F. capucina* Desm., *F. intermedia* Grun., *F. construens* var. *binodis* (Ehr.) Grun. and *F. construens* var. *venter* (Ehr.) Grun. This diatom complex corresponds to the *Fragilaria—Epithemia turgida* v. *granulata* DAZ—JZ 4 (Latałowa 1982b).

A distinct fall in the number of species was observed in the sediment layer at 45 cm. The generally poor flora was represented by single brackish-water and freshwater diatom specimens. Their presence in the sediment is indicated on the diagrams by a „+" sign.

CONCLUDING REMARKS

The limited inflow of sea water into the northern part of Lake Żarnowiec, which diatom analysis has confirmed, is linked with the final phase of the Littorine transgression in the southern Baltic Sea. In the study area, according to Rosa (1963), it took the form of a short-lived ingression of sea water which led to the formation of a series of isolated, shallow lakes. The northern reaches of the river Piaśnica probably aided the inflow of sea water into Lake Żarnowiec.

The presence of Subboreal brackish-water lakes has been confirmed in a few other locations along the Polish coast (Fig. 7).

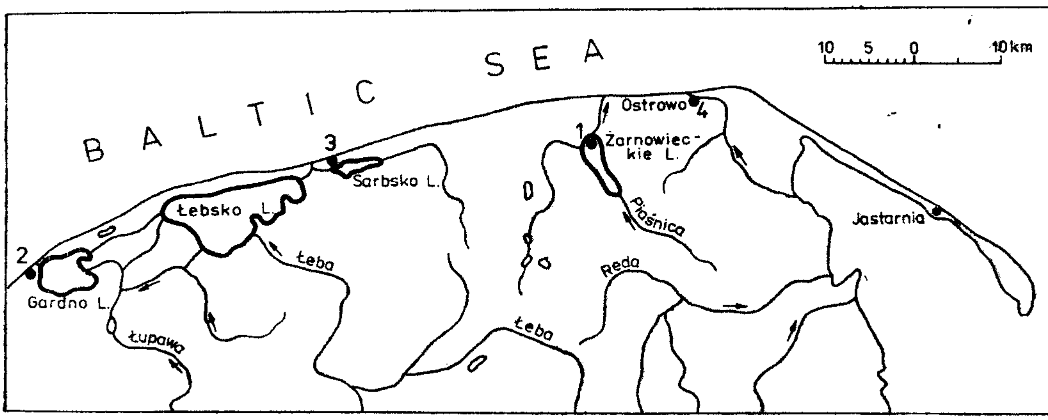

Fig. 7. Map showing the localities of Subboreal brackish-water sediments in the shore zone of the southern Baltic Sea: 1 — Lake Żarnowiec, 2 — Lake Gardno, 3 — Sarbska Bar, 4 — Ostrowska Upland

Palaeogeographical studies carried out in the vicinity of Lake Gardno have shown, for instance, that lacustrine sediments originating during the Subboreal phase of the Littorine Sea occur in the series of sediments forming the Gardnieńska Bar, to the west of Rowy (Fig. 7) (Bogaczewicz-Adamczak et al. 1981). That the lake, probably a coastal lagoon formed after ingression of sea water, contained brackish water is confirmed not only by the gyttjas with *Cardium* shells present in the sediments, but above all, by the so-called „lagoon elements" dominant in the diatom flora, especially the occurrence in huge numbers of *Campylodiscus* and *Diploneis* species, which together comprise around 94% of the frustules contained in the sample.

In addition, the existence of sediments typical of a shallow brackish-water lake was confirmed during stratigraphic and palaeoecological studies of the bar areas on the Gardnieńsko-Łebska Lowland — on the western part of the Sarbska Bar, to be more precise (Fig. 7) (Tobolski 1979). In Tobolski's opinion, that lake arose on the bar itself during the early Subboreal period as result of hydrological changes brought about by the transgression of the sea. The age of the algal gyttja (4610± 259 years BP) lying on the sandy sediments shows that this was the Subboreal phase of the Littorine transgression, synchronic with the eustatic minimum between phases L IV and L V of the transgression in southern Sweden (Berglund 1971).

During a palaeoecological study whose object was to reproduce the sedimentation conditions in the northern part of the Ostrowska Upland (Fig. 7), it was discovered that the Baltic had played an important part in the formation of this area too (Bogaczewicz-Adamczak unpubl. mat.). In the first half of the Subboreal period, an area formerly occupied by an Atlantic peat-bog was taken over by a lake, a continuation of the Late Glacial water body. A diatom complex characteristic of the Littorine sediments of the Baltic was found in the early Subboreal sediments. Predominant in the diatom flora were halophilous oligohalobous and mesohalobous species, typical of shallow, brackish-water lakes. The small numbers of pelagic zone diatoms indicates that this area was not directly affected by the sea's transgression, only the water table rose as a consequence of this process. As a result of the inundation of this low-lying accumulation level during the maximum of the Littorine transgression a lake was formed which existed as a shallow, short-lived, slightly saline lagoon.

The material on Lake Żarnowiec presented in this paper applies only to the shallow, northern end of the lake, which was covered with *Cladium mariscus* reed swamp during the Boreal and Atlantic periods (Latałowa 1982b). The ingression of sea water during the Littorine transgression initiated lacustrine sedimentation here. There is no evidence either for the penetration of sea water to the deeper parts of the then-existing lake, or for the existence of a Littorine bay or fjord which, according to Roszkówna (1964), filled the entire lake channel. Pollen analysis and macrofossil analysis from a locality some 2 km from the southern shore of the lake rule out the possibility of a bay ever having existed here. These analyses have shown that since the start of the Holocene, land communities have dominated the peat-bog covering this part of the Lake Żarnowiec channel. These communities have developed under the high water table conditions characteristic of river valleys and lakesides (Latałowa 1982a, b).

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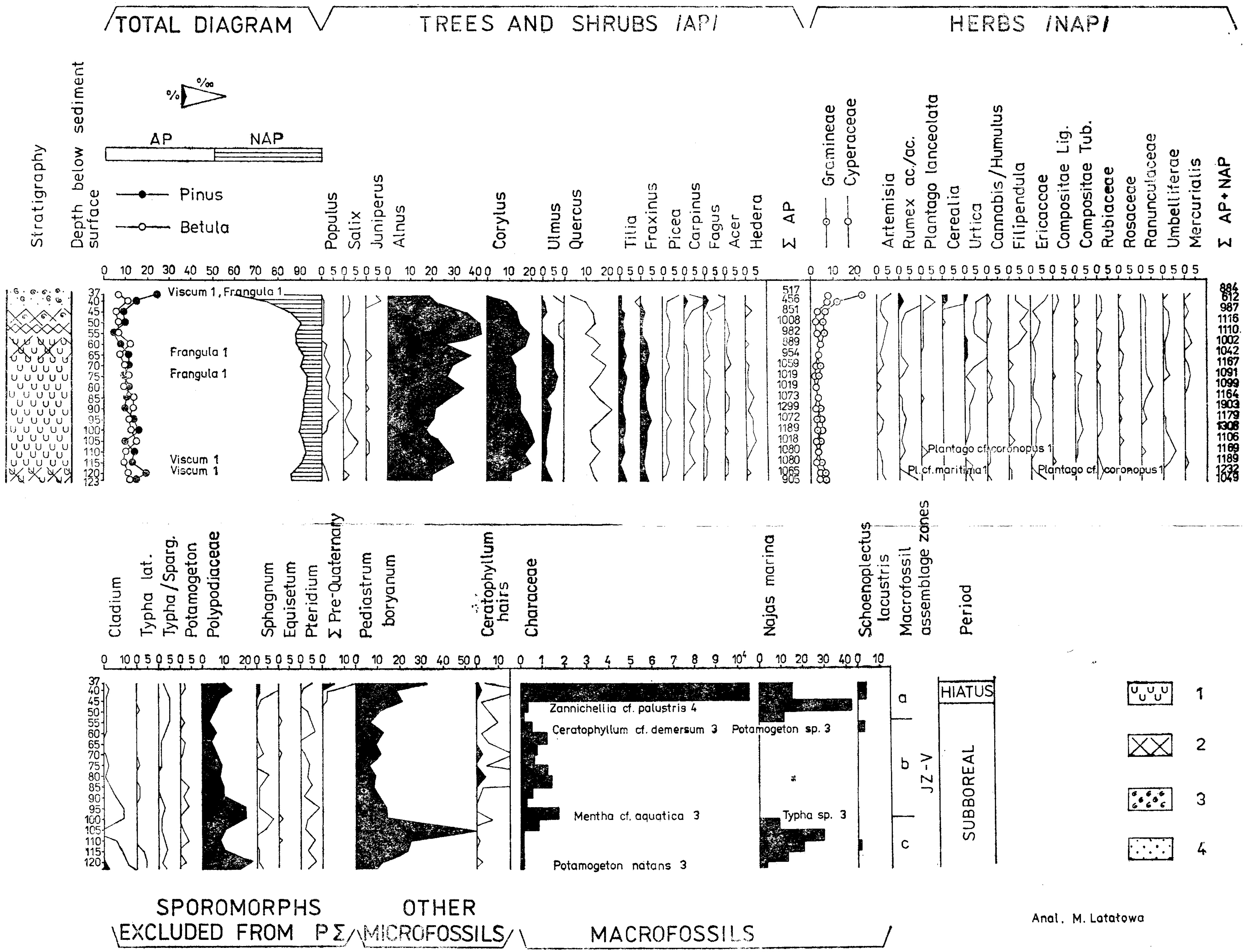

Fig. 2. Percentage pollen diagram and a simplified graph of the absolute number of macrofossil plant remains contained in 100 cm³ of sediment. Sediment symbols after Aaby (1979) 1 — calcareous gyttja, 2 — detritus gyttja, 3 — mollusc shells, 4 — sand

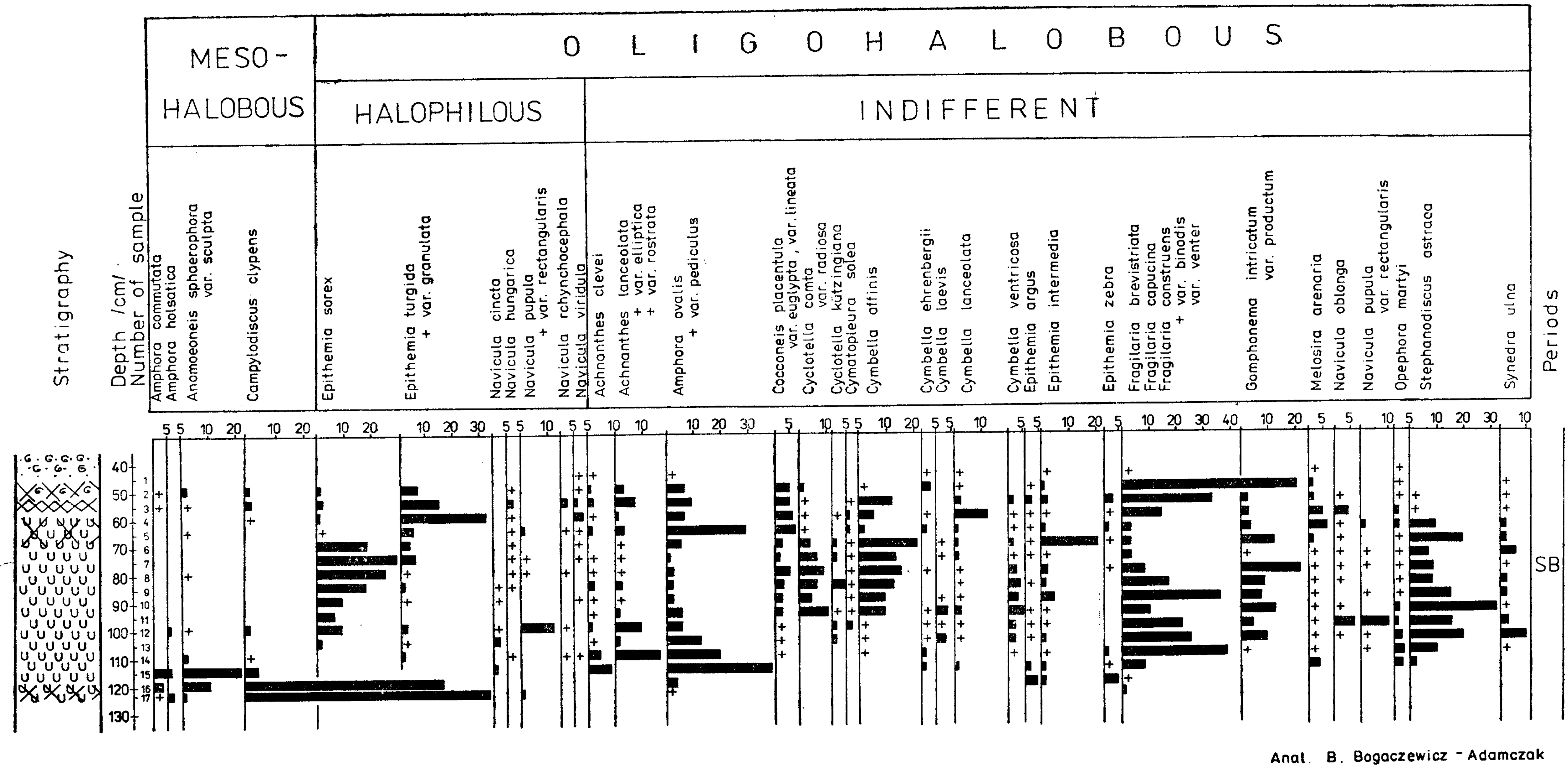

Fig. 3. Percentages of selected diatom species (above 1%) at different depths. Sediment symbols as for Fig. 2