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INVESTIGATIONS ON CRUSTACEAN AND MOLLUSCAN REMAINS IN THE UPPER SEDIMENTARY LAYER OF LAKE BALATON

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Investigations of the sediment and bed of Lake Balaton have been started towards the end of last century. The work became more intense in the thirties when the siltation of the lake, first of all in the Keszthely-Bay has been realized as an important practical problem. However, the rich special literature published on the topics until 1960 presented not too wide basis for the practical solving of siltation (VITUKI, 1963), calling our attention to the complexity and difficulties of the problem.

The first comprehensive work concerning the influencing and regulatory factors of the siltation of the lake was published in 1961 by SZESZTAY. Thereafter, a team under the guidance of VITUKI carried out numerous investigations between 1961 and 1964 in order to determine the degree and inducing factors of siltation (VITUKI, 1963; 1966).

It is clear from these results that the role of the living kingdom of the lake has not properly been elucidated in siltation. Consequently, the numerical values of "biological sediment" could only very roughly be estimated when calculating the degree of siltation (VITUKI, 1966, p. 74). In our opinion this is caused by the fact that only very few exact data are at our disposal connected both with the bioproduction of Lake Balaton (BÖSZÖRMÉNYI, 1966; ENTZ, 1954, 1959) and the modern sedimentological investigations (MÜLLER, 1969), on the basis of which, one could really estimate the amount of biological sediment formed annually.

The present paper gives an account of one part of the results obtained within a collaboration between the Sedimentological Laboratory of the University of Heidelberg and the Biological Research Institute of the Hungarian Academy of Sciences, started in autumn 1968. The starting point of the common investigations was to carry out similar complex investigations on the sediment of Lake Balaton as had been done on the Lake of Constance (MÜLLER, 1966; 1967).

The aim of the present work was to determine the frequency and relative amount of crustacean and molluscan remains in the upper 15 cm thick mud layer of different regions of the lake. We wanted to answer the following questions:

1. Are the *Dreissena* shells suitable for the determination of the rate of siltation in Lake Balaton?

2. Can the composition of animal remains of the young sediment give information on the understanding of the present relations prevalent in the lake?

Collecting places and methods

Seven mud samples were collected from the upper 15 cm thick layer of each 25 transversal sections of the lake between 2—13 September, 1968 (MÜLLER, 1969, p. 606). Those five of the sections have been investigated in detail where zoological studies had also been carried out previously (ENTZ et al. 1963; PONYI, 1966; 1969; PONYI et al. 1967; BIRÓ et al. 1968). The localization and denomination of the sections is given in *Fig. 1* while their detailed description can be found in the papers of SEBESTYÉN (1960) and MÜLLER (1969).

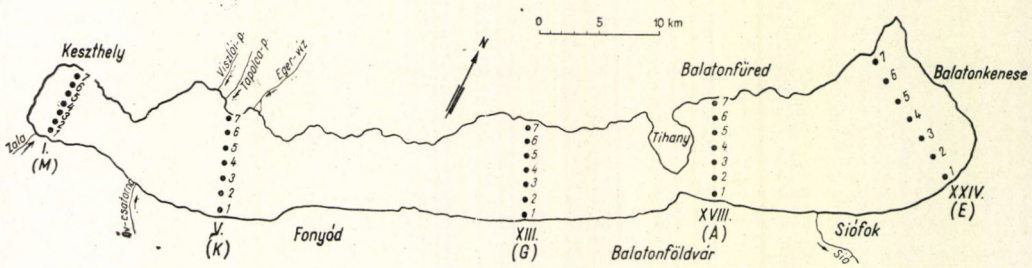

Fig. 1. Places of sample takings on the lake. The capitals in parentheses are the designations of sections used in earlier works

Taking into consideration the special circumstances present in Lake Balaton, the sample taking was carried out by means of a special "mud-core sampling" tool constructed for this purpose in the Sedimentological Laboratory (Heidelberg). It is a squared tube of 10 cm diameter and of 40 cm height, its wall is of 5 mm thickness and its lower edge is sharpened. Its upper hole is closed by a metallic cover-plate being overlaid inside with a spongy layer and fixed by two srews in the manner that it can move up and down. When taking sample the tool sinks down into the mud because of its weight(in such a case the water can flow out between the edge of the tube and the cover-plate). When taking it out by a cord, the cover-plate seals hermetically rendering intact samples. After draining off the water the mud block can be separated into several parallel samples by means of an aluminium tube (15 cm in length, 3 cm in width). The sample does not contain the uppermost very loose layer of the mud being removed together with the water, and containing about 90% of the living animals. When the bottom was very hard, sample taking was carried out by a diver.

The evaluation of the animal remains found in the samples took place in the Sedimentological Laboratory of the University of Heidelberg. The mud cores were pressed out from the tubes by compressed air. Every sample contained a semifluid brownish and greyish white as well as a relatively more compact layer. The samples were cut into 5 parts. Each of them were mixed with water in separated glass cylinders and shaked carefully then washed with tap water using a bronze sieve of 40 μ mesh (the diameter of the frame is 10 cm). The material purified this way has been investigated and selected under a stereoscopic microscope using magnifications between $\times 6 - \times 140$.

The molluscan and Ostracoda shells were prepared without any further treatment whereas in the case of Cladocera also the method of FREY (1961) was applied according to necessity.

The remains of Cladocera and Ostracoda have been evaluated by a relative quantitative method in order to be able to describe the percentage changes of the populations. For the rough estimation of the quantitative relations, 4 categories were separated on the basis of the shells and fragments found in the samples:

1. "Rich" where the number of shells and fragments was about 500.
2. "Moderately rich" between 250 and 300,
3. "Poor", between 100 and 150,
4. "Very poor", where this number was about 50.

Occurrence of molluscan shell remains in the samples

It is characteristic that they occur in the great majority of the samples (94%) and they are more and more frequent when going to north from the axis of depth, in the deeper layers *(Figs. 2—6)*. This peculiar distribution of the molluscan shells is connected with the hydrographical and physiographical

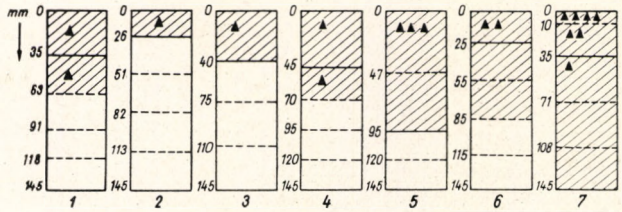

Fig. 2. The occurrence of molluscan shell remains in the mud samples of the Ist transversa section. Triangle indicates the occurrence of *Dreissena* in different layers, while the parts marked with lines indicates that of other species

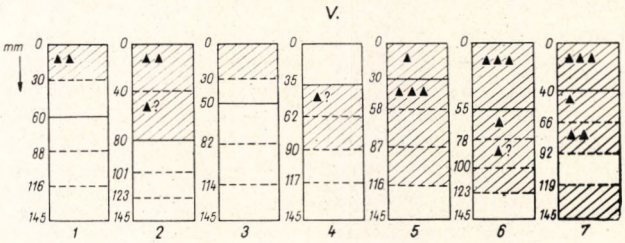

Fig. 3. The occurrence of molluscan shell remains in the mud samples of the Vth transversal section. (Explanation as in *Fig. 2)*

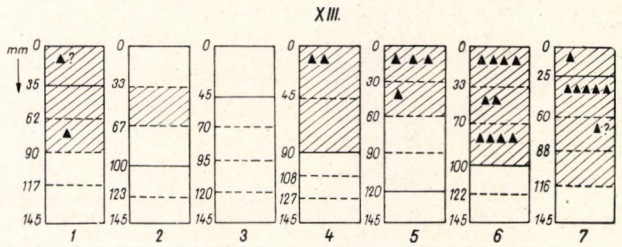

Fig. 4. The occurrence of molluscan shell remains in the mud samples of the XIIIth transversal section. (Explanation as in *Fig. 2)*

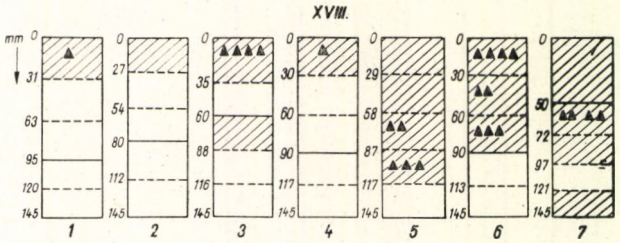

Fig. 5. The occurrence of molluscan shell remains in the mud samples of the XVIIIth transversal section. (Explanation as in *Fig. 2)*

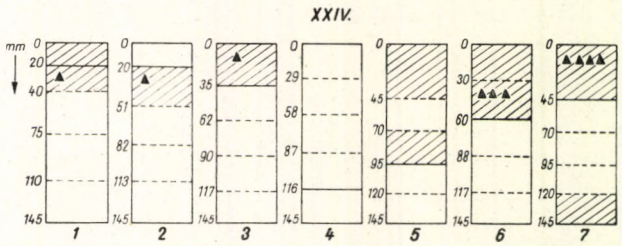

Fig. 6. The occurrence of molluscan shell remains in the mud samples of the XXIVth transversal section. (Explanation as in *Fig. 2)*

relations of Lake Balaton (flat, sandy shore on the south side, small continuous reeds; muddy north shore with well developed reeds; direction of wind, etc., see for more details: ENTZ and SEBESTYÉN, 1946). This explains also the fact that the samples collected on the northern parts were richer in species and genera than those collected on other regions of the lake.

Shell fragments of the following families and genera were found: *Dreissena, Unio, Anodonta, Pisidium, Valvata, Lithoglyphus, Lymnaea, Planorbidae, Ancylidae.* In the samples originating near the south shore (I—XXIV/1—1) only the shell fragments of *Dreissena, Unio, Anodonta* and *Pisidium* genera were found. *Valvata* shells were observed only in the I/7 and XVIII/7 samples of the northern shoreline.

The distribution of depth of *Dreissena* shells was investigated in detail, since they may be significant with regard to the determination of age (ENTZ et al. 1963). The microscopic investigations revealed that *Dreissena* shells do not occur below the following depths: 71 mm (Number I.), 92 mm (No. V.), 100 mm (No. XIII.), 116 mm (No. XVIII.) and 60 mm (No. XXIV.). This means that during about 35 years (considering the importation and propagation of this bivalve) the average siltation was probably not more than 71—116 mm (2—3 mm pro year) in the lake.

The average occurrence of depth of Dreissena shells in different sections and the values of the siltation calculated on the basis of the first are as follows:

No. I. (M)	48 ± 8 mm/35 years	1.4 ± 0.2 mm/year
No. V. (K)	66 ± 9 mm/35 years	1.9 ± 0.2 mm/year
No. XIII. (G)	76 ± 3 mm/35 years	2.2 ± 0.3 mm/year
No XVIII. (A)	62 ± 5 mm/35 years	1.8 ± 0.4 mm/year
No. XXIV. (E)	46 ± 4 mm/35 years	1.3 ± 0.4 mm/year
Average for the whole of Lake Balaton	59 ± 4 mm/35 years	1.7 ± 0.2 mm/year

In spite of the elements of uncertainty, the validity of the calculated values is supported by the results of other works, too. According to the pollen-analytical investigations of ZÓLYOMI (1953) the average siltation of the lake amounted 0.6—0.8 mm/year at Szigliget and 0.9 mm/year in the region of the port of Keszthely, calculated for the last thousand years (see also SZESZTAY, 1961; VITUKI, 1963). ENTZ et al. (1963) calculated a value of 3—4 mm/year on the basis of occurrence of *Dreissena* shells investigated in every 5 cm of a single section. SZESZTAY (VITUKI, 1966; p. 72) supposes a value of 0.5—1.0 mm/year of siltation on the basis of ZÓLYOMI's and ENTZ's investigations. Considering the increasing rate of siltation (SZESZTAY, 1961), the value of 1.7 mm/year calculated by us agrees with the above order of magnitude and seems to be real.

One can draw three conclusions from the investigations on *Dreissena* remains:

a) The rate of siltation has increased in the last several decades and now it is nearer to 2 mm/year than to 1 mm/year.

b) The results render it probable that the rate of siltation is the highest in the central regions of the lake between the axis of depth and the northern shore.

c) The age of the investigated 15 cm of the sediment can be estimated about 70—90 years.

Vertical and horizontal distribution of crustacean remains in the transversal sections

1. *Ostracoda shells*

Well preserved and a few broken Ostracoda shells were found in every sample. The relative amount of the shells, similarly as that of molluscs, gradually increases toward north *(Figs. 7—11)*. The shells of the following species have been identified in our material: *Ilyocypris gibba* (RAMDOHR), *I. bradyi* G. O. SARS, *Cypria ophtalmica* (JURINE), *Candona* sp., *Darwinula stevensoni* (BRADY et ROBERTSON), *Limnocythere inopinata* (BAIRD), *Metacypris cordata* (BRADY et ROBERTSON.)

The highest amount of shells was found in the case of the following Ostracoda species: *Candona* sp., *Darwinula stevensoni* and *Limnocythere inopinata*. The *Candona* shells belong at least to three species, the exact distinction of them on the basis of the structure of shells has not been possible (PETKOVSKI, 1969). Besides the *Limnocythere inopinata* another species of the same genus also occurs however, its identification has not been carried out. *Cypria ophtalmica* and *Metacypris cordata* were found only in the samples collected near the northern shore. Shells of the two *Ilyocypris* species occurred in limited number in the areas between the axis of depth and the northern shore.

Especially conspicuous is the distribution of depth of *Candona* and *Darwinula* shells in different sections *(Figs 7—11)*. While the rate of them was nearly identical both horizontally and vertically in the north-eastern basin and the nearest section, it was different in the other two sections (Keszthely-Bay and its surrounding). This difference manifests itself in the significant percentage occurrence of *Darwinula* shells observed in the latter two sections.

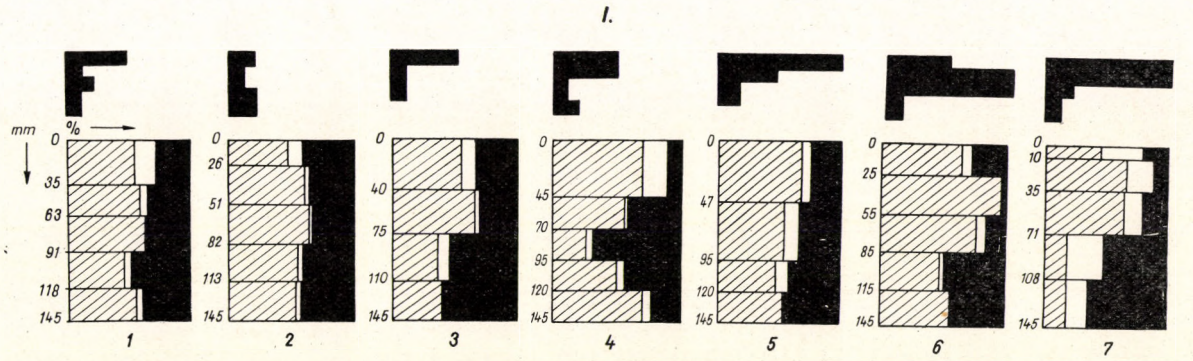

Fig. 7. The relative amount and percentage distribution of the Ostracoda shells in the mud samples of the Ist transversal section. Part marked with lines = *Candona;* black = *Darwinula;* white = other Ostracoda. Above the rectangle showing the percentage distribution, the relative amounts of shells found in the different layers are demonstrated on the basis of the 4 categories described in the methodological part

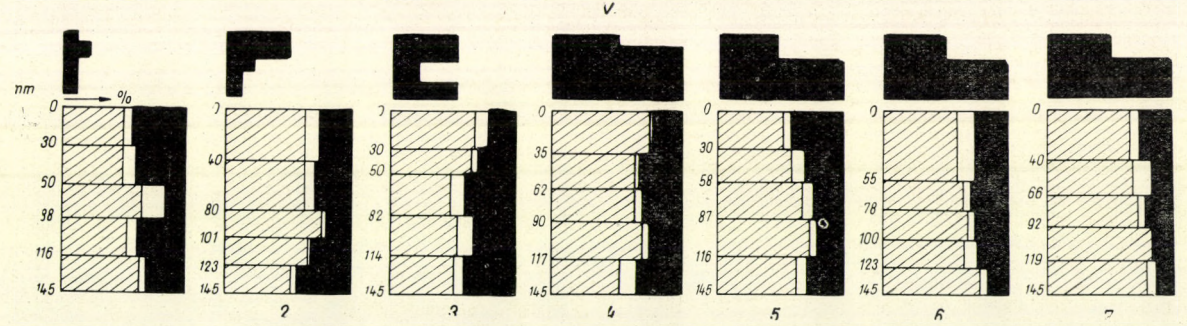

Fig. 8. The relative amount and percentage distribution of the Ostracoda shells in the mud samples of the Vth transversal section. (Explanation as in *Fig. 7)*

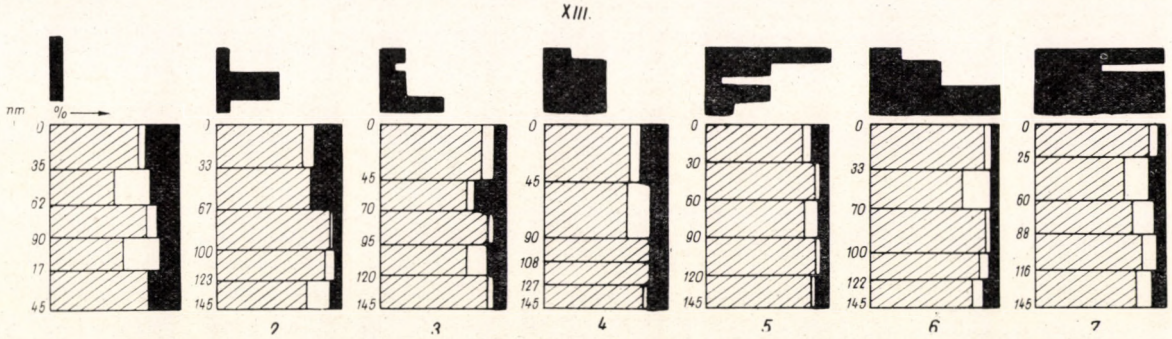

Fig. 9. The relative amount and percentage distribution of the Ostracoda shells in the mud samples of the XIIIth transversal section. (Explanation as in *Fig. 7)*

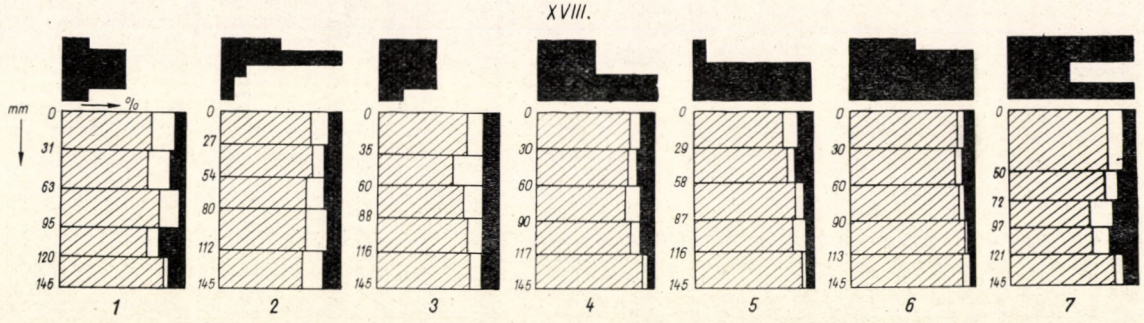

Fig. 10. The relative amount and percentage distribution of the Ostracoda shells in the mud samples of the XVIIIth transversal section. (Explanation as in *Fig. 7)*

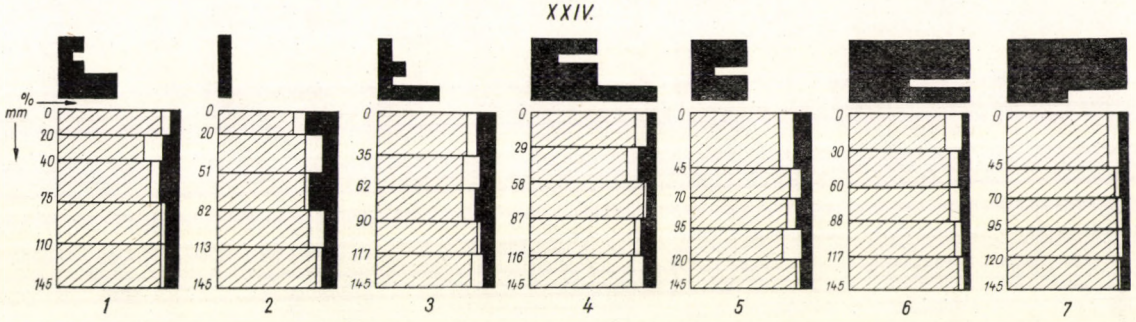

Fig. 11. The relative amount and percentage distribution of the Ostracoda shells in the mud samples of the XXIVth transversal section. (Explanation as in *Fig. 7*)

The change of *Candona—Darwinula* relation in favour of the latter indicates, according to the present ecological knowledge (KLIE, 1926; 1938; ENTZ et al. 1963; PONYI, 1966; 1969; PONYI et al. 1971), that the amount of detritus increased in the given area, causing the more intense propagation of the *Darwinula* population. Thus we are of the opinion that not only former times can be reconstructed but also the problems of present situation can be better evaluated on the basis of changes observed in the distribution of the Ostracoda shells in the mud layer of about 80 years, when carrying out high enough number of investigations. Even the present data evidence that detritus could be formed to a much higher extent in the Keszthely-Bay and its surrounding because of the presence of richer macrovegetation than in other regions of the lake.

The rate of living *Candona-Darwinula* individuals in the same sections as st own by the overale results of investigations carried out on the meiobenthos in 1962, 1965, 1966 and 1967 (spring, summer and autumn) is as follows:

No. I. (M)	*Candona*	46%
	Darwinula	53%
No V. (K)	*Candona*	31%
	Darwinula	69%
No. XIII. (G)	*Candona*	48%
	Darwinula	51%
No. XVIII. (A)	*Candona*	47%
	Darwinula	51%
No. XXIV. (E)	*Candona*	42%
	Darwinula	48%

Comparing the precentage distribution of the living animals and the shells found in the sediment, one has to draw the conclusion that the amount of detritus increased on the surface of the mud in the last years. The rates of living *Candona—Darwinula* individuals have changed in recent 5 years and show values in the whole area of Lake Balaton comparable to the shell investigations of the sediment in Keszthely-Bay.

2. *Cladoceran remains*

Our observations concerning the qualitative composition of Cladocera species as well as the stage of the shell fragments are similar to those obtained by SEBESTYÉN (1965; 1969; 1970) in the deeper layers of the sediment. The remains of the most frequent species were also identical except one.

The relative amount of the total Cladocera shell remains is different in the various sections *(Fig. 12)*. Although these data are roughly estimated, the decreased amount of shell remains in the Keszthely-Bay is conspicuous.

Alona species of large body size *(affinis, quadrangularis)* are preponderant in every sample. They represented more than 50% in every sample as expressed in the percentage of identifiable fragments.

Alona species were followed in order, depending on the sections, either by *Monospilus dispar* or *Bosmina longirostris*, rarely by *Alonella rostrata (Figs 15—17)*. *Bosmina* remains deserve greater attention among these species since this group of Cladocera can give valuable information concerning the changes of the lake (GOULDEN and FREY, 1963). A comparison of the amount of *Bosmina*, *Monospilus* and *Alonella*, related to each other *(Figs 15—17)* reveals that a significant percentage of *Bosmina* occurs in the mud samples

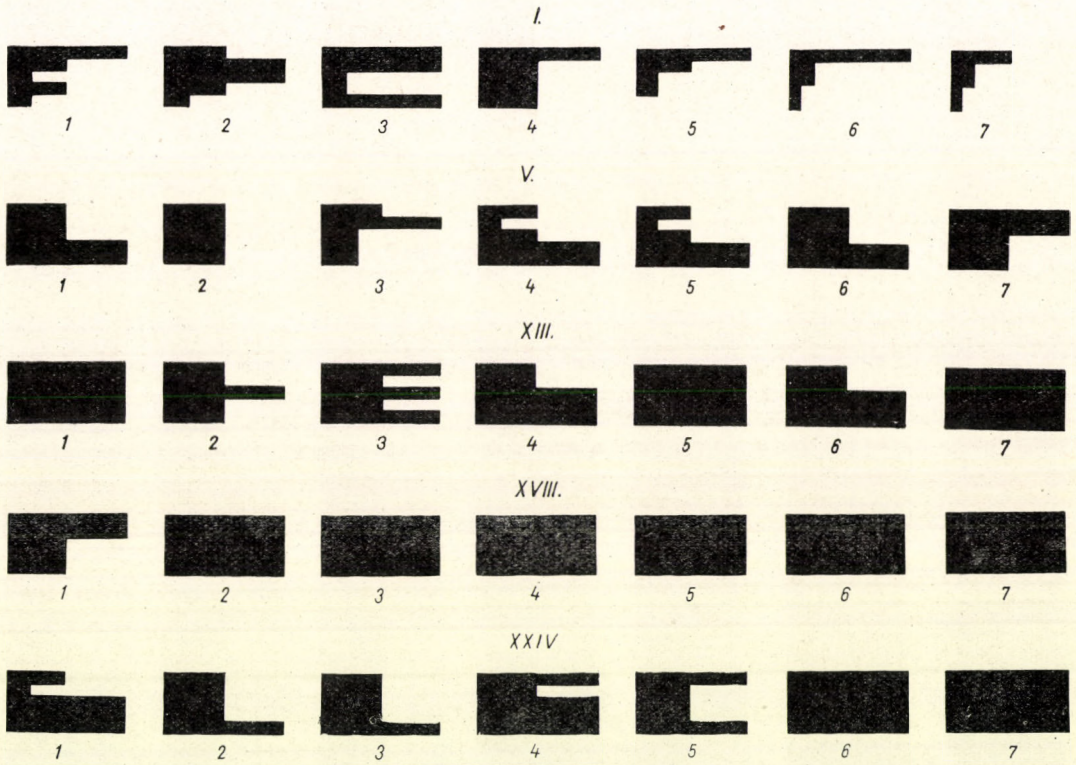

Fig. 12. The vertical and horizontal changes of the relative amount of total Cladocera shell remains in the mud samples of the transversal sections on the basis of the 4 categories described in the methodological part

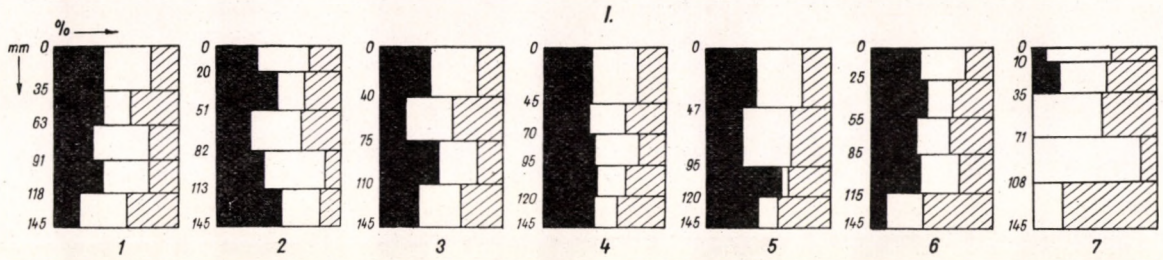

Fig. 13. The percentage distribution of *Monospilus*, *Alonella* and *Bosmina* remains in the mud samples of the Ist transversal section. *Monospilus* = black; *Alonella* = white; *Bosmina* = parts marked with lines

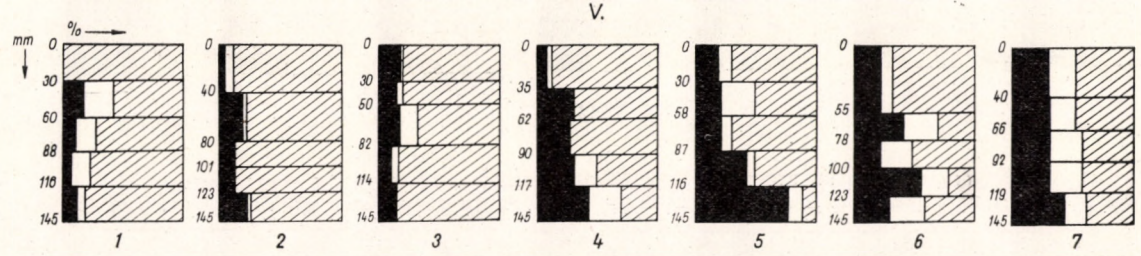

Fig. 14. The percentage distribution of *Monospilus*, *Alonella* and *Bosmina* remains in the mud samples of the Vth transversal section. (Explanation as in *Fig. 13)*

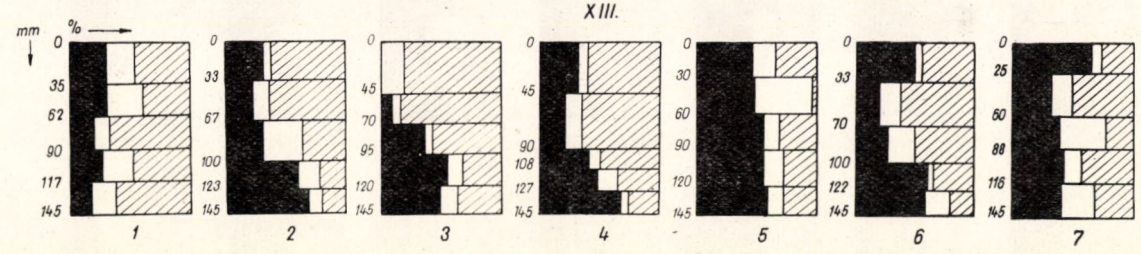

Fig. 15. The percentage distribution of *Monospilus*, *Alonella* and *Bosmina* remains in the mud samples of the XXIIIth transversal section. (Explanation as in *Fig. 13)*

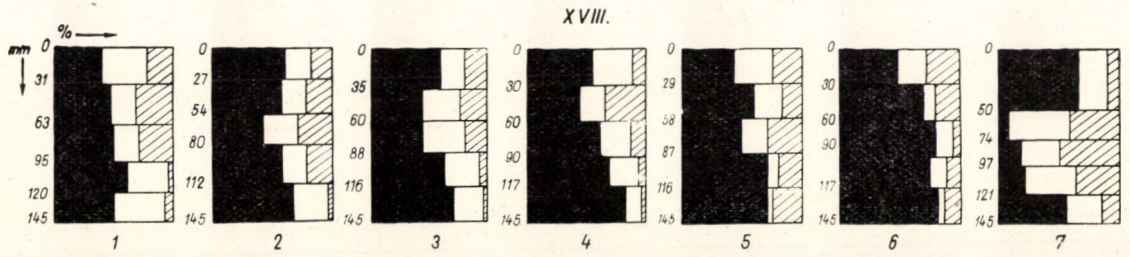

Fig. 16. The percentage distribution of *Monospilus*, *Alonella* and *Bosmina* remains in the mud samples of the XXVIIIth transversal section. (Explanation as in *Fig. 13)*

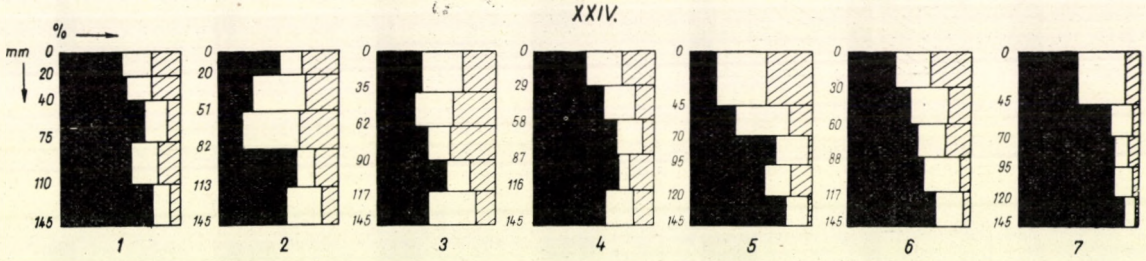

Fig. 17. The percentage distribution of *Monospilus*, *Alonella* and *Bosmina* remains inthe mud sample of the XXIVth transversal section. (Explanation as in *Fig. 13)*

of the Vth and XIIIth sections of the south-western basin. This high percentage occurrence may be attributed either to the decrease of the other two mud-living species or the real increase of number of *Bosmina*.

The data of SEBESTYÉN (1965; 1969; 1970) prove that *Monospilus* and *Alonella* belonged to the most common species in the sediment of New Holocene epoch similarly as in present times, and fragments of *Bosmina* were rare. The recent results of zooplankton investigations (SEBESTYÉN, 1960; 1964; PONYI, 1968) reveal that the *Bosmina* population is not significant in the lake at present. As it was shown by earlier collections (north-eastern basin 1936—38; south-western basin 1925; SEBESTYÉN, 1953; PONYI, 1965), this species could be significant in the south-western basin contrasting with the north-eastern one. In the open water in front of Révfülöp (between the Vth and XIIIth sections) it amounted nearly 100% of the Crustacean plankton in spring-time (PONYI, 1965).

Thus one can assume that the changes of percentage distribution of *Bosmina* fragments are really connected with the quantitative changes of the animals living that time. *Bosmina* population was most probably significant in the south-western basin during the last 70—90 years *(Figs 14—15)* and their restriction can be attributed to the changes in the character of the lake.

Summary

Investigating 15 cm long and 3 cm wide mud-cores taken from 7 points of each 5 transversal sections of Lake Balaton it has been established:

1. The frequency and relative amounts of Mollusca and Ostracoda shells rapidly increases toward north especially between the axis of depth of the lake and the northern shore. The relative amount of Cladocera fragments is lower in the cores of the Keszthely-Bay than in the other investigated sections.

2. The ratio of *Candona* and *Darwinula* shells compared to each other seems to be connected with the amount of detritus. The decrease of the latter causes a change in the ratio in favour of *Candona* while an increase brings on opposite effect.

3. The population of *Bosmina longirostris* might have been significant in the south-western basin of Lake Balaton during the last 70—90 years.

4. On the basis of occurrence of *Dreissena* shells in depth, considering 35 years, the average siltation of Lake Balaton can be estimated as 1.7 mm/year. The siltation seems to be most intense in the central regions of the lake.

Acknowledgement

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A BALATON FELSŐ ÜLEDÉKRÉTEGÉBŐL SZÁRMAZÓ RÁK (CRUSTACEA) ÉS PUHATESTŰ (MOLLUSCA) MARADVÁNYOK VIZSGÁLATA

Ponyi Jenő

Összefoglalás

A Balaton 5 keresztszelvénye 7—7 pontjáról származó 15 cm hosszú és 3 cm átmérőjű iszapfúrásminták vizsgálat alapján a következőket állapíthatjuk meg:

1. A Mollusca- és Ostracoda-héj gyakorisága és relatív mennyisége a déli parttól az északi felé rohamosan nő, különösen a tó mélységi hossztengelye és az északi partvonal között. A Cladocera töredékek relatív mennyisége kisebb a Keszthelyi-öböl fúrásmintákban, mint a többi vizsgált szelvényben.

2. *Candona* és *Darwinula* héjak egymáshoz viszonyított arányának változása úgy látszik összefügg a formált szervesanyag (detritusz) mennyiségével. Kevés detritusz esetében ez az arány a *Candona* felé, ellenkező esetben a *Darwinula* felé tolódik el.

3. Az elmúlt 70—90 évben a *Bosmina longirostris* állomány jelentős lehetett a Balaton DNY-i medencéjében.

4. A *Dreissena*-héj mélységi elhelyezkedése alapján, 35 évet alapul véve, a Balaton átlagos feltöltődése 1,7 mm-re tehető. A feltöltődés üteme úgylátszik a tó középső területein a legintenzívebb.