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LATE MIOCENE MOLLUSC BIOSTRATIGRAPHY IN THE EASTERN PART OF THE PANNONIAN BASIN (TISZÁNTÚL, HUNGARY)

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Abstract: Biostratigraphic study of Late Miocene (Pannonian and Pontian) endemic molluscs from east Hungarian part of the Pannonian Basin revealed the relative persistence of the deep water association (*Paradacna abichi, Dreissenomya digitifera, "Pontalmyra" otiophora, Valenciennius* etc.) during the Late Pannonian and Pontian. Consequently, the earlier interpretation of these forms as Pontian or Lower Pontian ones, and definition of the Early and Late Pontian substages by them, should be revised.

The occurrences of the sublittoral association can be divided into two stratigraphic units: *Congeria czjzeki* and *Lymnocardium* aff. *winkleri* indicate Late Pannonian, while their descendants, i.e. *C. zagrabiensis* and *L. majeri*, indicate Pontian age. In the littoral facies zone 3 stratigraphic units were identified: a Late Pannonian one, an Early Pontian one (with *Lymnocardium decorum*), and a Late Pontian one (with *Prosodacnomya*). Evolution from *L. decorum* to *Prosodacnomya* took place between 7.7 and 7.0 million years, according to magnetostratigraphic and seismic data.

Basinward progradation is demonstrated by the geographic distribution of molluscs. The Pannonian-Pontian boundary, just like the other isochronous surfaces, has a dip towards the interior of the basin. It runs in the delta plain facies in the northern part of the Tiszántúl area, further to the south it intersects the slope facies, and reaches the basement at the feet of the southeastern Hungarian pre-Neogene highs. Consequently, in the northern part of Eastern Hungary Pannonian, and in the southern part Pontian sediments give the major part of the basin fill.

Key words: Pannonian Basin, Late Miocene, biostratigraphy, *Mollusca*.

Introduction

The Central European Pannonian Basin is a Neogene extensional basin encircled by the Carpathians, Alps and Dinarides. In the Middle Miocene it was filled by an inland sea that became converted into a lake by the Late Miocene. Genetic isolation an abrupt change in life conditions gave rise to a rapid endemic evolution of the molluscs of the lake. Sediments of this Late Miocene (and Earliest Pliocene) Pannonian lake cover a large area in Austria, Slovakia, Ukraine, Hungary, Romania, Slovenia, Croatia, Serbia, Bosna, and the Czech Republic. In this paper, the mollusc biostratigraphy of the east Hungarian part of the Pannonian Basin is discussed.

In contrast to the western and southern parts of the Pannonian Basin, where the holo- and faciostratotypes of the Pannonian and Pontian regional stages were designated, mainly in nearshore facies (Fig. 1), the study area includes the relatively poorly known deepest subbasins of the Pannonian Basin (Fig. 2). In Eastern Hungary the Upper Miocene deposits are known only from borehole samples, as they are covered by Pliocene and Quaternary sediments. Drilling for hydrocarbons in the area started in 1918 (Schmidt 1939) and the number of boreholes rapidly increased. Late Miocene molluscs of the cores were determined by Sümeghy (in Schmidt 1939), Schréter (1940), Széles (1962, 1966, 1968, 1971a, 1971b), and Magyar & Révész (1976).

Biostratigraphic subdivision for the area was established by Széles (1966, 1971a). She applied Strausz's (1971) tripartite system with minor modifications, differentiating "Lower Pannonian", "transitional", and "Upper Pannonian" units. The increasing amount of borehole data and rapid development of the other stratigraphic methods, however, revealed several contradictions in this zonation (Magyar 1991; Korpás-Hódi et al. 1992; Juhász & Magyar 1993).

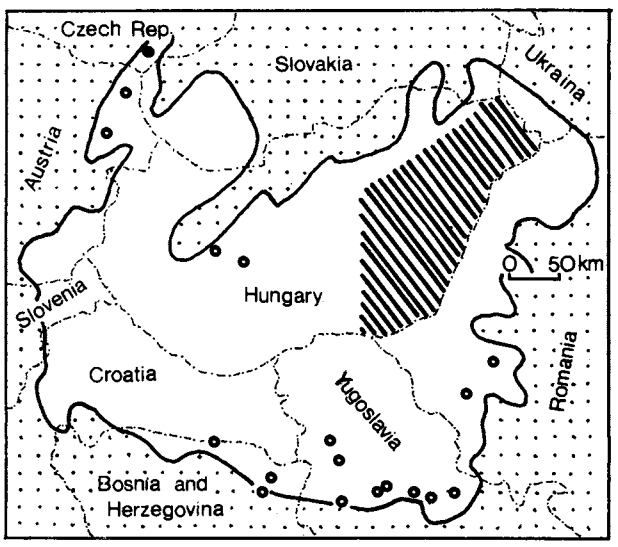

Fig. 1. The study area "Tiszántúl" (hatched) in the Pannonian Basin. Dotted area indicates the basin margin. Thick circles mark the locations of the Pannonian and Pontian holo- and faciostratotypes; they are situated in the western and southern part of the basin.

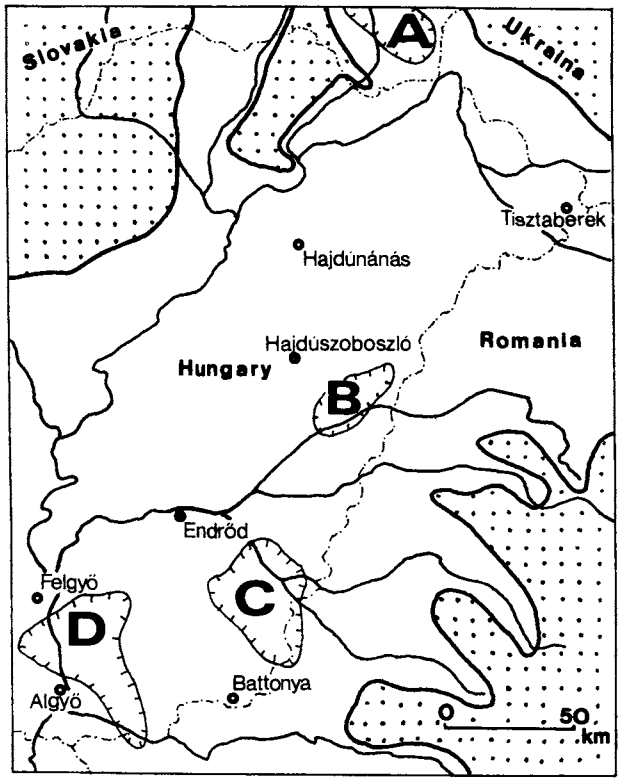

Fig. 2. The deep subbasins in and around Eastern Hungary and the locations referred to in the text. Dotted area indicates the basin margin. **A** - Transcarpathian Basin; **B** - Derecske Basin; **C** - Bekes Basin; **D** - Mako-Hodmezovasarhely Basin.

I revised the determinations of molluscs in all available core samples, in order to give a new biostratigraphic interpretation that is consistent with the results of magnetostratigraphy, sedimentology and seismic stratigraphy. The new model, however, does not completely fit the system proposed by Stevanovic (1951, 1990a) and accepted by IUGS RCMNS.

Material and methods

I determined the fossils of 650 core samples from the Tiszántúl area. Beside the material deposited in the MOL Rt. Oil & Gas Laboratories, I utilized collections of the Hungarian Geological Institute, the Geological and Paleontological Department of József Attila University, Szeged and the Geological Department of Eötvös Loránd University, Budapest.

Preservation of the molluscs was usually poor. They are generally moulds and casts, and, rarely, calcite pseudomorphs. Original shell material was preserved only in samples from minor depth, from the delta plain and alluvial plain facies.

The majority of this material was first determined by Széles (1971a), and a considerable part of it was recorded only in internal reports of the oil company. In these reports and publications *Dreissenomya digitifera* was usually determined as *Congeria banatica*, and *"Pontalmyra" otiophora* as *Lymnocardium desertum*.

Stratigraphic interpretation of the material was carried out in three steps.

Firstly, we compare the distribution of the mollusc assemblages with that of the different seismic- and lithofacies (Pogácsás et al. 1990; Juhász & Magyar 1993).

Secondly, I established a biostratigraphic subdivision, based on the evolution of the molluscs, within the different facies.

Thirdly, the biostratigraphic units were correlated by means of radiometric, magnetostratigraphic, and seismic data.

Stratigraphic terminology

At first sight, the Late Miocene stratigraphic terminology of the Pannonian Basin is rather confusing. Lőrenthey (1900), modifying the original proposal of Roth (1879), applied the name "Pannonia" for the brackish water sequence of the Pannonian lake. He divided the Pannonian stage into Lower and Upper Pannonian substages (Fig. 3).

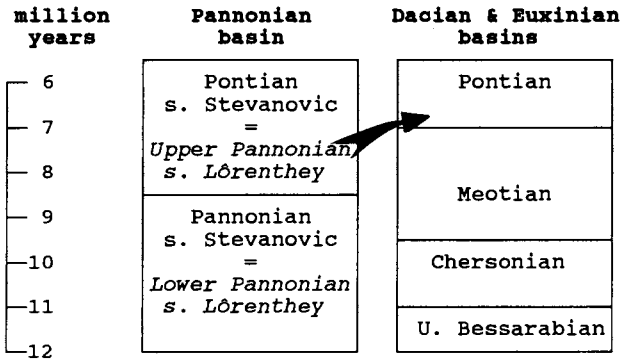

Fig. 3. Late Miocene regional stages of the Central and Eastern Paratethys. The arrow indicates date and direction of a major migration event in molluscs.

In a late phase of the existence of the Pannonian lake a number of its molluscs emigrated eastward to the Dacian and Euxinian Basins. Based on this event, Stevanovic (1951) proposed the introduction of the name "Pontian", established earlier in the Euxinian Basin, for Lőrenthey's Upper Pannonian. The first appearance of these molluscs in the Pannonian Basin, however, well preceeded their emigration and appearance in the Dacian and Euxinian Basins. Thus, this correlation introduced an error of about 1.5 - 2.0 Ma (Müller & Magyar 1992a) (Fig. 3).

However, as Stevanovic's view is accepted by the International Union of Geological Sciences, Regional Committee on Mediterranean Neogene Stratigraphy, in this paper I will use this terminology.

Mollusc associations and their age

In order to avoid confusion of facies changes with stratigraphic boundaries I made an attempt to carry out stratigraphic subdivisions within different facies zones. The facies distributions and mollusc associations of the area are described in detail elsewhere (Juhász & Magyar 1993). Here I give a simplified facies description in favour of a concise stratigraphic interpretation.

Deep water facies

Widespread and thick deep water sediments (delta slope deposits and pelitic deep water formations) form the overwhelm-

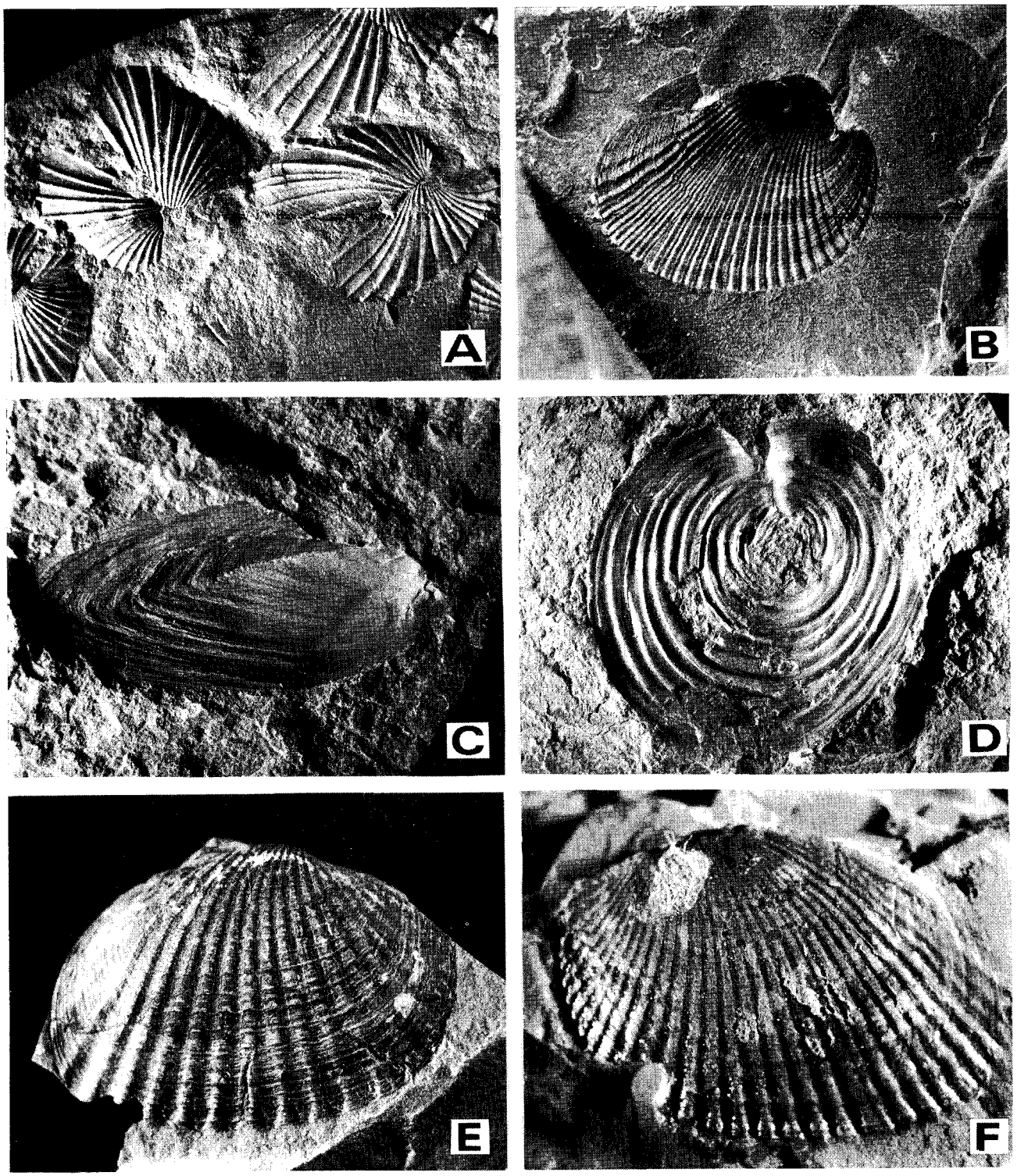

Fig. 4. Late Miocene molluscs from Eastern Hungary. **A** - *Paradacna abichi* (R. Hornes). Borehole Algyo-8, 2200 m; Pontian. **B** - *"Pontalmyra" otiophora* (Brusina). Borehole Felgyo-1, 2282 m; Pontian. **C** - *Dreissenomya digitifera* (Andrusov). Borehole Endrod-5, 2539 m; Pontian. **D** - *Valenciennius* cf. *reussi* Neumayr. Borehole Algyo-16, 1811 m; Pontian. **E** - *Lymnocardium majeri* (M. Hornes). Borehole Felgyo-I, 2282 m; Pontian. **F** - *Lymnocardium* aff. *winkleri* (Halavats). Borehole Hajdunanas-2, 1176 m; Late Pannonian. All specimens are deposited in the collection of MOL Hungarian Oil and Gas Company Ltd., Budapest.

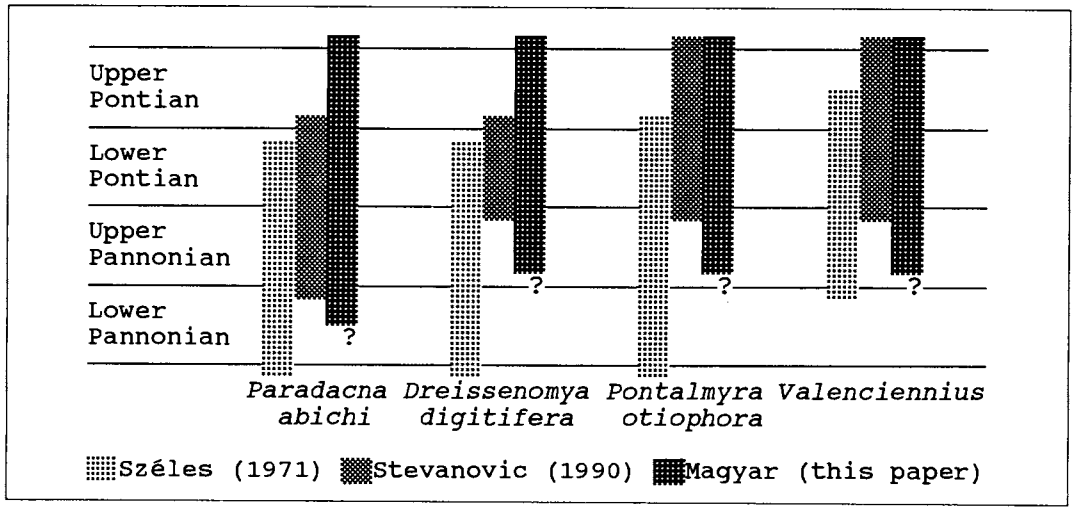

Fig. 5. Time span of some deep water molluscs of the Pannonian lake, as understood by different authors. *Paradacna abichi*, *Dreissenomya digitifera*, *"Pontalmyra" otiophora* and *Valenciennius* persisted from Pannonian to Late Pontian time.

ing part of the Late Miocene basin fill in Eastern Hungary (Juhász 1991). They contain a characteristic assemblage of molluscs, consisting of *Paradacna abichi* (R. Hörnes) (Fig. 4A), *P.* cf. *lenzi* (R. Hörnes), *Paradacna* sp., *"Pontalmyra" otiophora* (Brusina) (Fig. 4B), *Congeria* sp. ex group *Modilioformes* Andrusov, *Dreissenomya digitifera* (Andrusov) (Fig. 4C), *Valenciennius* cf. *reussi* (Neumayr) (Fig. 4D), *"Radix"* sp., and planorbids.

Diverging views exist on the age of this association (Fig. 5).

It was held to be Pannonian (and, in some interpretations, Early Pontian) in Hungary (Strausz 1941, 1971; Barnabás & Strausz 1991; Széles 1971a; Fig. 5a). Occurrence of *Paradacna abichi*, *"Pontalmyra" otiophora*, and *Valenciennius reussi* was reported from Pannonian surface outcrops together with *Congeria partschi*, *C. czjzeki*, *Lymnocardium sopronіense*, etc. (Szádeczky-Kardoss 1938; Strausz 1942a, 1951; Chivu et al. 1966; Korpás-Hódi 1981).

On the other hand, these forms, except *Paradacna abichi*, are regarded as typical Pontian, and in the case of *Dreissenomya digitifera* as typical Early Pontian, forms in Croatia, Serbia and Romania (Stevanovic 1951, 1990b; Basch 1990; Sokac 1990; Marinescu & Papaianopol 1990, etc.; Fig. 5b).

According to the east Hungarian record, these molluscs were rather persistent forms. They display morphological stasis at least during the Late Pannonian and Pontian. In the borehole Kaskantyú 2, *Dreissenomya digitifera* was found in 1010 m depth (Korpás-Hódi et al. 1993), about 200 m below the top of magnetic anomaly 5 (8.9 Ma) (Elston et al. 1990), that is, well within the Pannonian. On the other hand, this deep water association overlies the Upper Pontian littoral facies with *Congeria rhomboidea* and *Budmania* in southeastern Hungary (Magyar 1991). Therefore, we conclude that these forms appeared in the Pannonian and persisted until the Late Pontian when the deep water environment disappeared in the Pannonian Basin (Fig. 5c).

Sublittoral facies

The diversity of the fauna increases from the deep water facies towards the littoral facies. The sublittoral facies includes the upper part of the delta slope deposits with fine-grained sediments.

For the time being, two biostratigraphic units can be established within the sublittoral facies:

A - The older one (Upper Pannonian) contains *Congeria czjzeki* and *Lymnocardium* aff. *winkleri*. Their occurrences are geographically restricted to the northern half of the Tiszántúl area (Fig. 6).

B - The younger one is Pontian. It includes *Congeria zagrabiensis*, a descendant of *C. czjzeki*, and *Lymnocardium ma-*

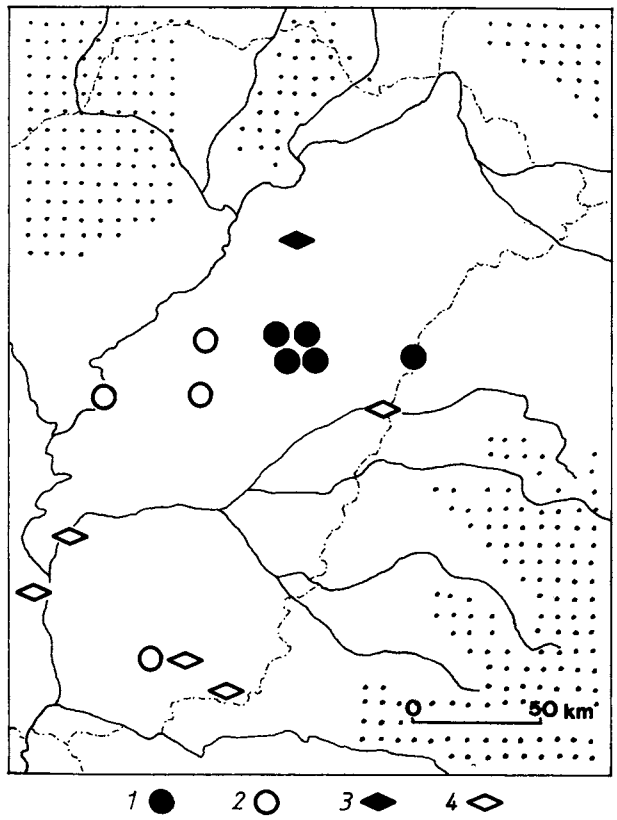

Fig. 6. Geographical distribution of some sublittoral molluscs in Eastern Hungary. The Pannonian *Congeria czjzeki* (1) and *Lymnocardium* aff. *winkleri* (3) are probable ancestors of the Pontian *C. zagrabiensis* (2) and *L. majeri* (4), respectively. Note the geographical separation of older and younger forms within each group.

jeri (Fig. 4E), which in turn stems from the group L. winkleri (Fig. 4F). Other Pontian forms, such as *Pteradacna pterophora, Congeria croatica*, etc. occur here as well. This unit, however, is restricted to the southern half of the Tiszántúl area (Fig. 6).

To make a distinction between *Congeria czjzeki, C. zagrabiensis*, and *C.* sp. ex group *Modioliformes* Andrusov, especially when the specimens are poorly preserved and compressed, is very difficult. In addition, they are possibly linked with intermediate transitional forms. In Fig. 6 only the localities of typical and unambiguously determinable specimens are marked.

Littoral facies

Shallow water molluscs were abundant in the delta front and delta plain environments as well as on rocky shores. Species of the genera *Lymnocardium (banaticum, penslii, hungaricum, schmidti*, etc.), *Congeria (triangularis, balatonica, ungulacaprae*, etc.), and *Dreissena auricularis* were the most common forms in well aerated, strongly agitated water with a sandy substratum. The most widespread shallow water associations, however, are enclosed in fine-grained sediments, deposited in flooded delta plain environment, and include *Lymnocardium decorum, Melanopsis decollata, Dreissena serbica*, and species of *Prosodacnomya, Unio, Anodonta, Viviparus, Hydrobia*. Different forms of *Paradacna* ex group *P. abichi* (cf. *radiata* and *okrugici*) still occur here in probably somewhat deeper water intercalations.

Within the littoral facies zone three biostratigraphic units can be identified.

A - Pannonian molluscs are known only from one locality: Sümeghy (in Schmidt 1939) reported *"Melania" escheri, Melanopsis vindobonensis, Melanopsis pygmaea, Melanopsis bouei, Congeria subglobosa* from the Tisztaberek borehole, NE Hungary (Fig. 7). (Unfortunately, this material has been lost, so the determinations cannot be confirmed.)

B - Occurrence of *Lymnocardium decorum* indicates Early Pontian age. This form appears in a NW-SE running zone through the Tiszántúl area (Fig. 7).

C - The evolutionary relationship of *Lymnocardium decorum* and *Prosodacnomya* is disscused by Müller & Magyar (1992b). The genus *Prosodacnomya* originates in *L. decorum*, and, according to magnetostratigraphic and seismic data (Pogácsás et al. 1993), first appeared between 7.7 and 7.0 Ma. This Upper Pontian forms is restricted geographically to the southern half of the Tiszántúl area (Fig. 7).

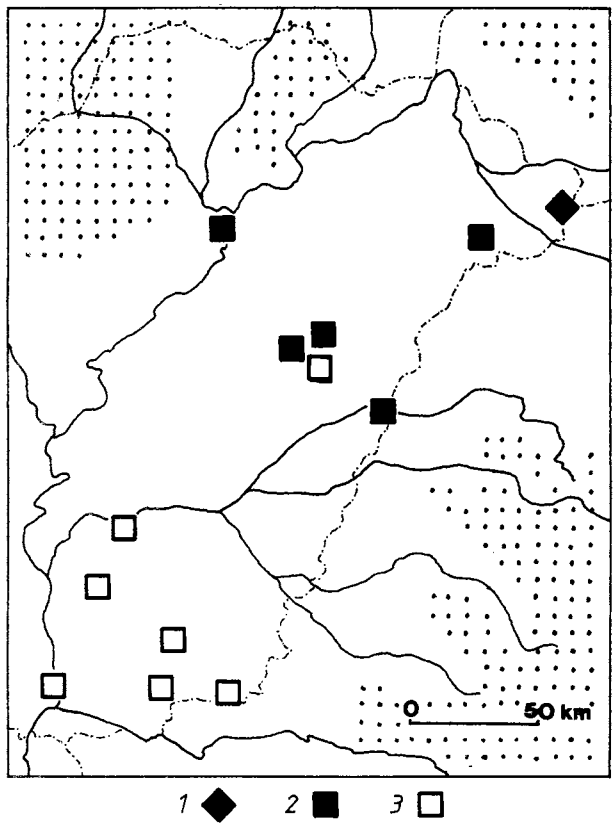

Fig. 7. Geographical distribution of some littoral molluscs in Eastern Hungary. **1** - *Melanopsis pygmaea, M. vindobonensis, Congeria subglobosa*, etc. (Pannonian); **2** - *Lymnocardium decorum* (Lower Pontian); **3** - *Prosodacnomya* (Upper Pontian). Geographical separation of molluscs of different age is conspicuous.

Correlation of the stratigraphic units

A biostratigraphic correlation chart for different facies of Eastern Hungary is given in Fig. 8.

Numerical ages are inferred from combined use of radiometric dating, magnetostratigraphy, and seismic stratigraphy. Radiometric (K/Ar) ages (Cserepes-Meszéna 1978; Balázs & Nusszer 1987) and magnetostratigraphic data (Cooke et al. 1979; Rónai

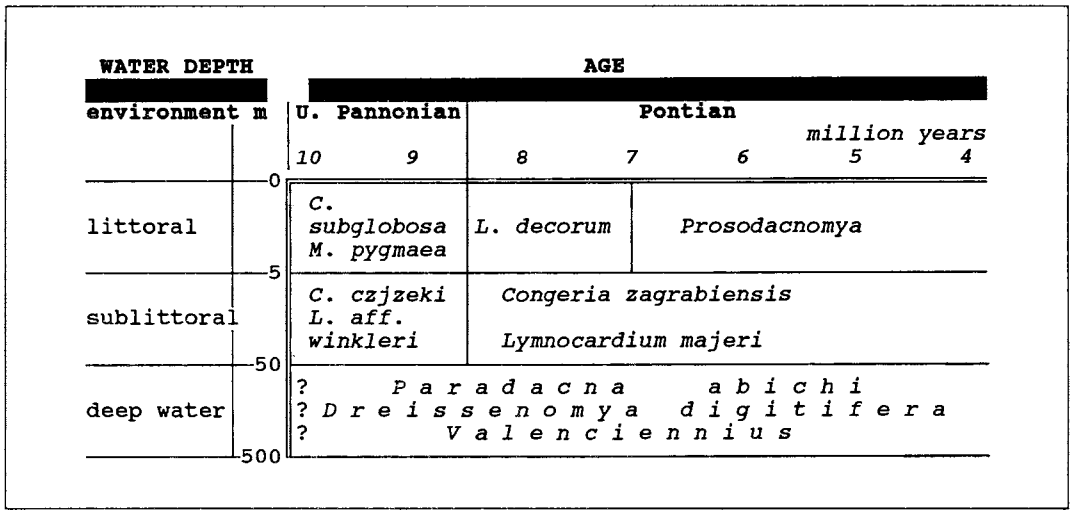

Fig. 8. Biostratigraphic correlation chart for different facies of Eastern Hungary. Further explication is in the text.

& Szemethy 1979; Elston et al. 1990; Lantos et al. in press) were connected and crosschecked by means of seismic profiles (Pogácsás 1987; Horváth & Pogácsás 1988; Pogácsás et al. 1989). On this basis, Pogácsás and co-workers mapped different time horizons in the southern part of the Tiszántúl area (Pogácsás et al. 1988, 1990, 1993).

We have no data from Lower Pannonian formations. In the northern part of the Tiszántúl area, where they are thick, there are only a few drillings; in the relatively well-known southern part, in turn, the Lower Pannonian record is very thin (condensed) or entirely missing. It is possible, however, that some of the deep water forms, especially *Paradacna abichi*, are present in the Lower Pannonian formations as well.

Discussion

According to sedimentological and seismic evidence, the Pannonian Basin was filled by prograding delta systems. The shallow water environment more or less continuously moved towards the interior of the basin, while the deep water environment, like the lake itself, shrank. This process is reflected in the geographical separation of the molluscs of different age (Figs. 6 and 7).

If we consider Tiszántúl fossil record together with that of the adjacent regions, this pattern becomes obvious. Concerning the shallow and brackish water molluscs (molluscs of marine origin, like cardiids and dreisseniids) we find that older (Pannonian) ones occur only close to the basin margin: Bükk Mountains (Schréter 1939), Hernád Valley (Sümeghy 1939; Bartha 1971), Eastern Slovakia and Ukrainian Transcarpathia (Jiříček 1985; Vialov 1986; Petrashkevich & Orshinskaya 1971), Tisztaberek borehole in northern Tiszántúl area (Sümeghy in Schmidt 1939), northern foreland of the Apuseni Mountains (Chivu et al. 1966), valleys of Crisul Repede (Mihaila & Marinescu 1971) and Crisul Negru (Pana 1971), Banat (Marinescu et al. 1977, and many others), Morava Valley (Miletic-Spajic 1959) and Belgrade area (Pavlovic 1928) (Fig. 9).

The extent of Lower Pontian shallow water forms is, in general, restricted to the more basinward zone. In the northern part they are known only from boreholes. They come to the surface in the eastern foreland of the Apuseni Mountains (Sümeghy 1939; Strausz 1942b; Chivu et al. 1966; Wanek 1978) and follow the edge of the basin all through the Banat (Marinescu et al. 1977; Stevanovic 1990c) (Fig. 9).

The Upper Pontian shallow water molluscs occur in an even more restricted area, in the interior part of the basin (Fig. 9).

Consequently, the basin fill of the different subbasins is of different age. The Transcarpathian basin, and the adjacent northeastern Tiszántúl area, situated closer to the sediment source, contain a thick Pannonian sequence, while the brackish lacustrine Pontian is entirely missing here (Jiříček 1990). Further to the south, next to the Derecske through, the Pontian is represented only by Lower Pontian molluscs. In the Békés Basin, however, most of the basin fill is Upper Pontian (see also Mattick et al. 1988; Pogácsás et al. 1993). Thus, the Pannonian/Pontian boundary in Eastern Hungary dips to the south: in the northern part (Tiszaberek) it is above the delta plain facies zone, in the middle part (Hajdúszoboszló area) are it is somewhere between the delta plain and delta slope facies zones, while in the southern part it runs very close to the basement, even reaching it (Battonya and Algyő basement highs).

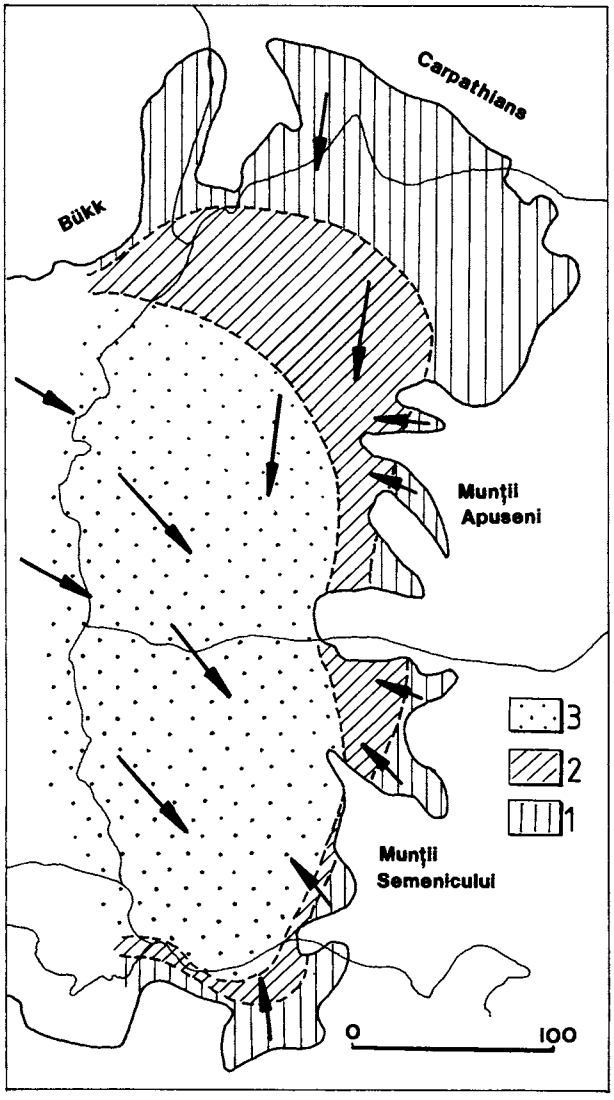

Fig. 9. Distribution of littoral molluscs of the Pannonian lake in the eastern part of the Pannonian Basin (simplified). **1** - Pannonian; **2** - Lower Pontian; **3** - Upper Pontian. Blank area indicates basin margin. The arrows indicate directions of sediment transport according to Pogácsás & Révész (1987), Jiříček (1990), Marinescu et al. (1977), Miletic-Spajic (1959), and Truklja & Kirin (1984). Correlation between the main sediment transport directions and the geographical width of zones of different age obviously reflects the progradation.

This picture considerably differs from the earlier stratigraphic considerations that were based on the vertical sequence of the facies (Sümeghy 1939; Strausz 1971; Széles 1971a; Dank & Jámbor 1987).

Implications for interbasinal correlation

Definition of the basal Pontian boundary in the Pannonian basin, on the basis of malacofauna, has recently been given by Stevanovic (1990a). He lists a great number of mollusc species that "appeared at the beginning of the Early Pontian (Novorossian, Odessian)". I think, however, that this definition is not unambiguous, since the appearances of the cited forms were

not isochronous. According to the Tiszántúl record, species of the deep water facies, such as *Paradacna abichi*, *"Pontalmyra" otiophora*, *Dreissenomya digitifera*, and the genus *Valenciennius* appeared earlier than, for instance, *Congeria praerhomboidea*, *Lymnocardium decorum*, *Lymnocardium ochetophorum*, and *Lymnocardium banaticum* in the sublittoral and littoral facies.

Similarly, if we mark the beginning of the Pontian by "the first appearance of common species on both sides of the Carpathians", as Stevanovic (1990a) suggests, we fail to get a correct correlation. Most, if not all of the common species evolved in the Pannonian Basin (Taktakishvili 1987; Müller & Magyar 1992b) and migrated only later to the Dacian (Marinescu & Papaianopol 1990), and Euxinian (Taktakishvili 1990) Basins (Fig. 3). That is, their first appearance in the respective basins is not synchronous, even if the vertical sequence of the facies (deep water to shallow water) is similar in the Pannonian, Dacian, and Euxinian Basins.

Conclusions

The new dynamic model that has recently been developed for the Late Neogene infilling of the Pannonian Basin is supported by the paleontological record. In the Eastern Hungary, where the deepest subbasins existed during the Late Miocene, the different subenvironments of the prograding delta systems and their shift towards the interior of the basin (prevailing N to S) can be followed by molluscs.

Consequently, in the northern part of Eastern Hungary, Pannonian, while in the southern part Pontian sediments give the major part of the basin fill. The Pannonian-Pontian boundary, like other isochronous surfaces, dips towards the interior of the basin (generally to the south).

To mark the Pannonian-Pontian, and Lower Pontian-Upper Pontian boundaries in the deep water facies by the appearances and disappearances of *Paradacna abichi*, *Dreissenomya digitifera*, *"Pontalmyra" otiophora*, and *Valenciennius* is impossible for the time being as they persisted from Pannonian to Late Pontian time.

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