GEOL. CROAT.	46/1	63 - 69	6 Figs.			ZAGREB 1993

UDC 550.834:551.782.1(1-924.55)

Original Scientific Paper

The Role of Seismic Stratigraphy in Understanding Biological Evolution in the Pannonian Lake (SE Europe, Late Miocene)

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Key words: Late Neogene, Seismic stratigraphy, Biostratigraphy, Mollusca, Evolution, Pannonian basin

Abstract

The combined use of seismic stratigraphy and mollusc biostratigraphy in Late Neogene lacustrine deposits of the Pannonian basin offers three new approaches:

First, the comparison of seismic facies and biofacies facilitates to make a distinction between biostratigraphic units and biofacies.

Second, seismic datum levels permit crosschecking of discrete (magnetic, radiometric, and biostratigraphic) data, thus dating evolutionary events.

Third, seismic monitoring of the sedimentary history of the basin helps in the understanding of the geographic distribution of molluscs (areals of younger forms are more and more restricted, due to progradation).

1. INTRODUCTION

High resolution seismic profiles are commonly used for facies analyses and stratigraphic investigation of basin areas. Palaeontologists are also engaged in creating facies- and chronological models of sedimentary basins. The combined use of the two methods, seismic stratigraphy and biostratigraphy, may result in more reliable reconstructions. Benefits of this kind of integrated research become especially obvious when the endemic and highly specialized nature of the basin's fauna throws difficulties in the way of extra- and intrabasinal biostratigraphic correlation. Such conditions existed in the Late Neogene Pannonian basin in Southeastern Europe (Fig. 1). The brackish water Pannonian lake that filled the basin in the Late Miocene (Pannonian and Pontian) and earliest Pliocene hosted a rich endemic fauna of molluscs, the stratigraphic and facies interpretation of which has given rise to much controversy. The present study deals with the initial results of the combined use of the two stratigraphic methods in the Pannonian basin.

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2. TECTONIC AND PALAEOGEOGRAPHIC SETTING

The Pannonian basin system is a back-arc type extensional basin behind the coeval Carpathian thrust belt. The subsidence of the Pannonian basin began in the middle Miocene when a set of discrete wrench fault related basins opened inside the Carpathian loop. The Pliocene, up to recent development of the region, has been controlled by thermal subsidence (ROYDEN & HORVÁTH, 1988; KÁZMÉR, 1990).

The Pannonian lake, situated in the Pannonian basin in the late Miocene with an approximately 100,000 km^2 water table, was a remnant of the early to middle Miocene Central Paratethys sea (Fig. 1). Its sediments are ranged into Pannonian and Pontian stages (PAPP et al., 1985; STEVANOVIĆ et al., 1990). For most of its 8 Ma existence, the lake was endorheic. Due to the uneven subsidence of the basin, several hundred, almost one-thousand-metre-deep parts existed in the lake for a long period of time. Infilling of the basin with sediments was determined by delta systems prograding mainly to the S and SE. In certain periods of its lifetime the lake had a connection with the Dacian and Euxinian basins. The nature of this connection, however, i.e.

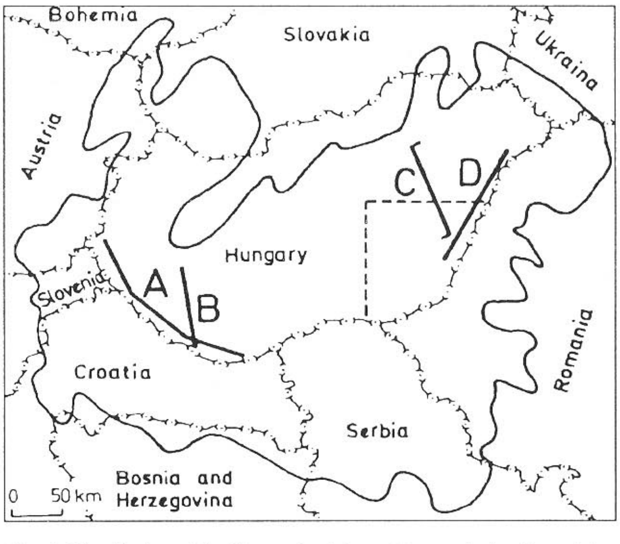

Fig. 1: Distribution of the Pannonian lake sediments in the Carpathian basin (the water table, however, had never covered such an extended area). Sections A to D in Fig. 2, dotted line indicates location of map series in Fig. 3 and profile in Fig. 4.

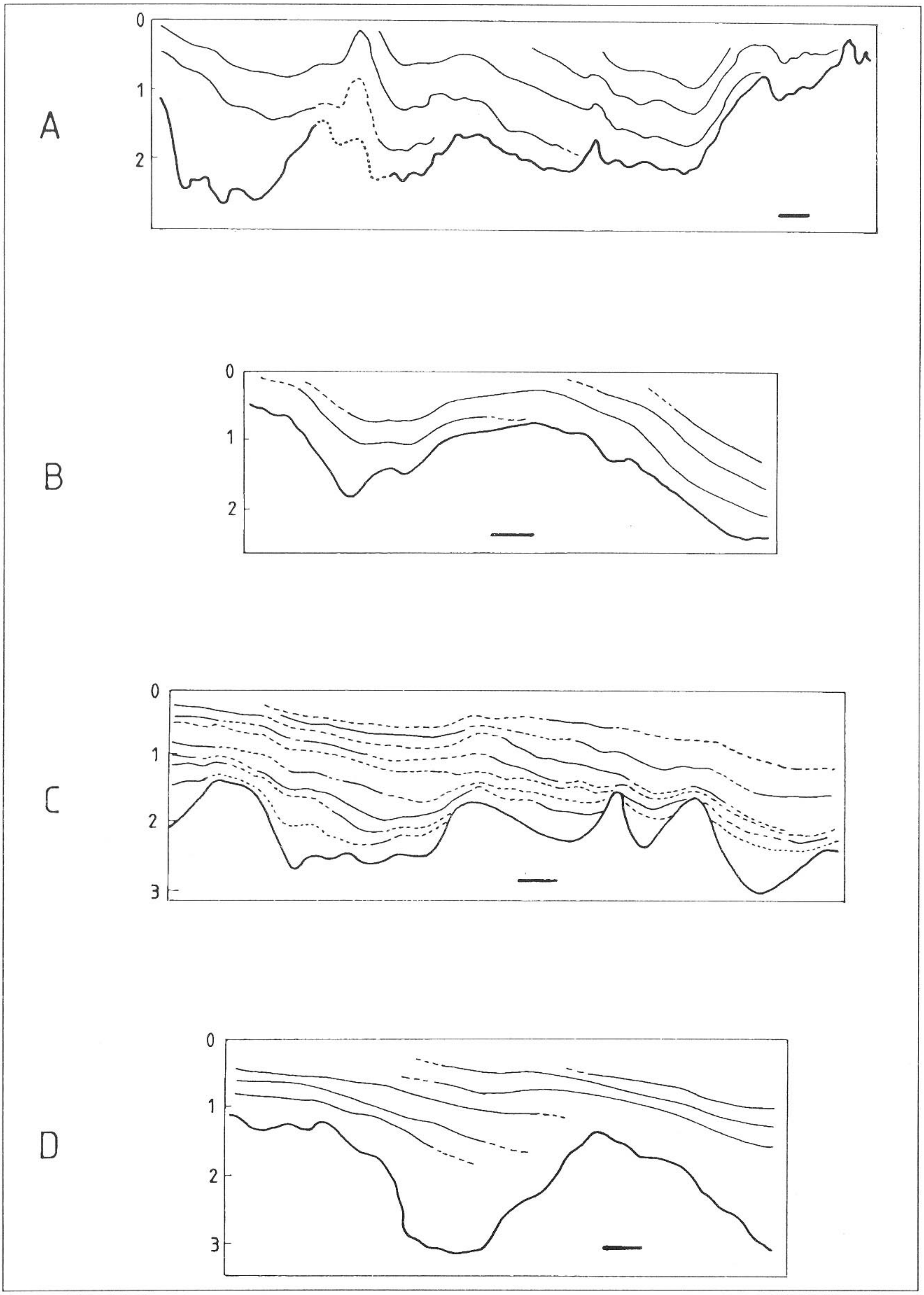

Fig. 2: Relative time lines identified on the basis of seismic events along composite seismic profiles. Note the general southward dip of time horizons. Thick line indicates the basement of the Pannonian. Vertical scale in two way time (sec.). Horizontal scale bar = 10 km. Location of the profiles (A to D) in Fig. 1. (From POGÁCSÁS et al., 1988, simplified.)

whether it was an overflow of the lake or a normal strait, is not yet clear.

3. DIFFICULTIES IN STRATIGRAPHICAL CORRELATION

For a long time stratigraphic schemes for Pannonian Lake deposits were solely based on benthic associations, evidently dependent on local ecological factors. Mainly this was why zonations of HALAVÁTS (1903), LÖRENTHEY (1906), STRAUSZ (1942), STEVANOVIĆ (1951), PAPP (1953) and KORPÁS-HÓDI (1987) often contradicted one another, thus no universally accepted biostratigraphic division exists. Extra-basinal correlation by molluscs was hindered or rendered impossible by the endemic character of the lake's biota, except for a restricted interval when a set of species emigrated from the Pannonian lake to the Dacian, Euxinian, Caspian, and even to the Aegean basins.

In almost all spots, the progradation resulted in a gradual shallowing of the lake, thus the sequences contain deep water associations in their stratigraphically older parts, and continuously shallower water ones upward. This universal pattern gave an illusion of isochrony for events which in fact were diachronous in different parts of the basin. E. g. deep water marls were for a long time regarded as Lower Pannonian because they were almost invariably found at the bottoms of the individual sections (boreholes). The benthic mollusc associations, changing accordingly to the facies, also evoked a similar illusion.

4. SEDIMENTARY HISTORY OF THE PANNONIAN LAKE

One way to understanding the stratigraphy of the sediments of the lake is the study of its infilling history. According to ROYDEN (1988), the extension and associated subsidence, the thermal history and related events were strongly diachronous and of varying importance throughout the different parts of the Pannonian basin. As a general rule, the centre of the subsidence shifted gradually from the north (Vienna basin, Transcarpathian basin) to the south and mainly to the southeast (southeastern part of the Great Hungarian Plain and adjoining areas in Croatia, Serbia and Romania).

The composite seismic profiles usually display a common pattern: the seismic datum levels dip towards the interior of the basin (in Hungary to the south or southeast), where they pinch out, or rather, the thickness of the depositional units drops below the seismic resolution (POGÁCSÁS et al., 1988)(Fig. 2).

These profiles prove that the main sources of sediments in the late Neogene were situated NW and N of the Pannonian basin, and a less important source took place in the NE. Consequently, the infilling of the basin was asymmetrical and predominantly determined by delta systems prograding in a southeastern and southern (or, in one narrow zone, in a southwestern) direction - not only in Hungary, but in a considerable part of Vojvodina as well (TRKULJA & KIRIN, 1984). Another consequence of this depocentre shift was that subbasins situated further south or southeast of the delta system were starving. Thus, several hundred-metre-deep subbasins existed in the lake with strongly condensed sedimentation for considerable time intervals. The lake's main body of water was also shifted southeastwards, while the northwestern parts were gradually transformed into alluvial plains, i.e. into drylands.

5. DATING OF THE PANNONIAN LAKE SEDIMENTS

Prospecting for hydrocarbons with high resolution seismic profiles resulted in a seismic grid covering almost all deep basins of Hungary containing sediments of the Pannonian lake. Composite seismic profiles enable lateral monitoring of seismic events over great distances. As seismic reflectors are considered to correspond to isochronous surfaces, relative and numerical datum levels can be drawn across the basin. Seismic datum levels permit crosschecking and harmonisation of discrete chronological (radiometric, magnetostratigraphic, or biostratigraphic) data and their extrapolation to other parts of the basin.

Some drillings on the Great Hungarian Plain penetrated volcanic rocks interbedded in Late Neogene layers (CSEREPES-MESZÉNA, 1978; BÁLAZS & NUSSZER, 1987). Magnetostratigraphic investigation have been carried out on several drillings on the Great Hungarian Plain (Dévaványa-1, Vésztö-1, Kaskantyú-2, Tiszapalkonya-1) and in the Transdanubian area (LANTOS et al., in press).

Crosschecking of the chronological data by seismic profiles has been performed without major contradictions (POGÁCSÁS, 1987; HORVÁTH & POGÁCSÁS, 1988; POGÁCSÁS et al., 1989). Mapping of numerical datum levels is, for the time being, restricted only to SE Hungary. In this area it revealed a general southeastward shift of the different environments, according to delta progradation, between 7.4 and 5.2 m.y. (Fig. 3). The general structure of the Pannonian, beginning probably at about 12 m.y. B.P. (KÓKAY et al., 1991), and Pontian seems to be similar all over the Hungarian part of the Pannonian Basin. .

6. CHRONOLOGY OF BIOLOGICAL EVENTS IN THE PANNONIAN LAKE

The fauna of the Pannonian lake, partly of marine, partly of continental origin, underwent a spectacular endemic evolution. Adaptive radiation led to specializa-

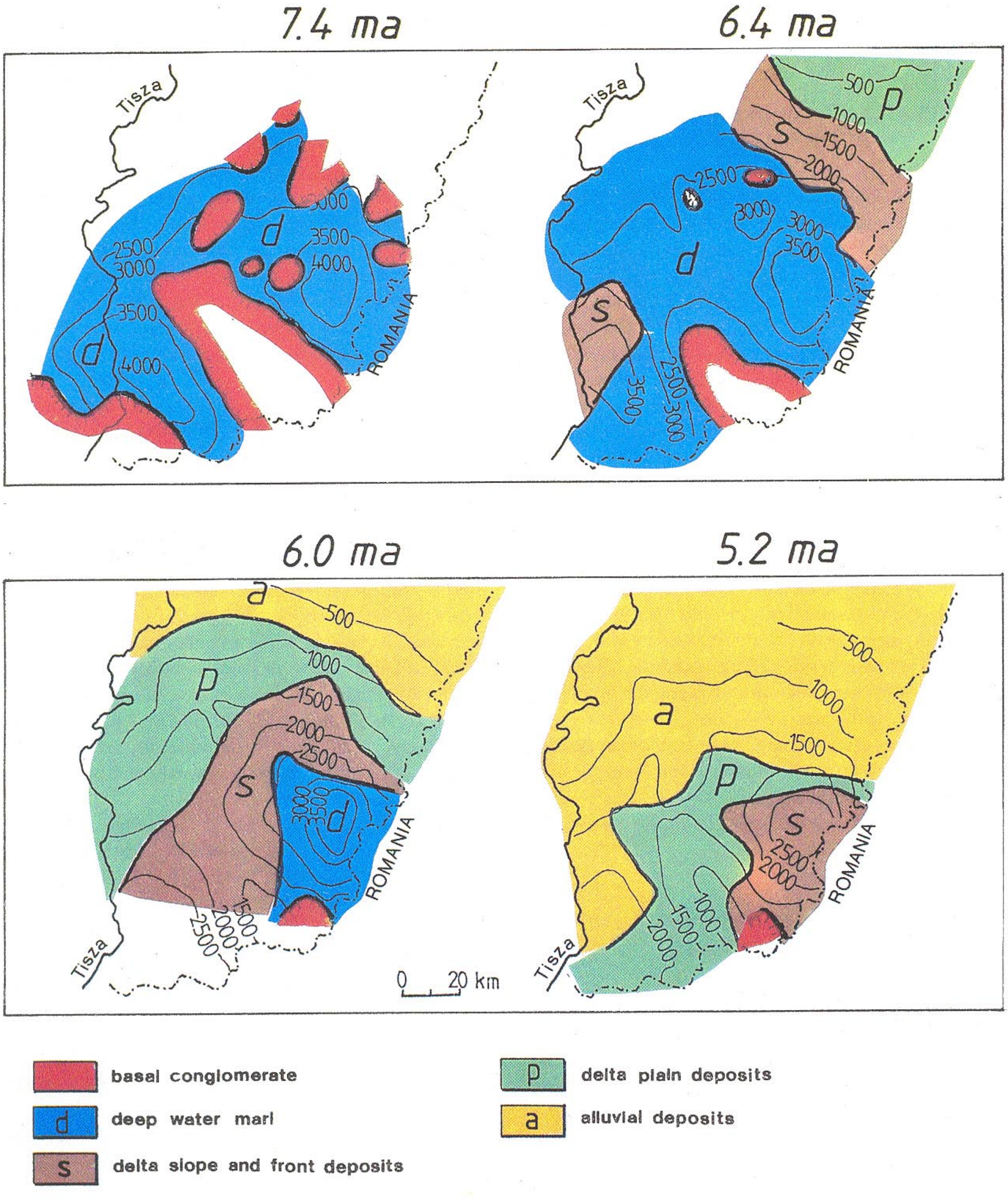

Fig. 3: Facies distribution in four time horizons in SE Hungary. Note the migration of the facies to the southeast. Saw-toothed line indicates pinching out zone with basal conglomerate formation. Isobath lines are in metres below sea level. Location of the area in Fig. 1.
d: deep water marl; s: delta slope - delta front deposits; p: delta plain deposits; a: alluvial deposits.

tions to the most diverse biotopes present in the lake, from lagoonal to deep water ones.

Comparison of seismic facies with mollusc biofacies proves this statement, and facilitates to discern between biochronological units and biofacies. To study this in detail, a subbasin of the Pannonian basin system was studied to carry out a detailed comparison of seismic depositional facies and biofacies. The infilling history of the southeastern Hungarian Békés basin (Fig. 4) is fairly well known from seismic and sedimentological investigations (MATTICK et al., 1988; POGÁCSÁS et al., 1989; K. JUHÁSZ et al., 1989). This study demonstrated that all the depositional environments recognized by seismic and well-log studies are characterized by more or less specific mollusc associations, from the deep water marls to the alluvial plain (POGÁCSÁS et

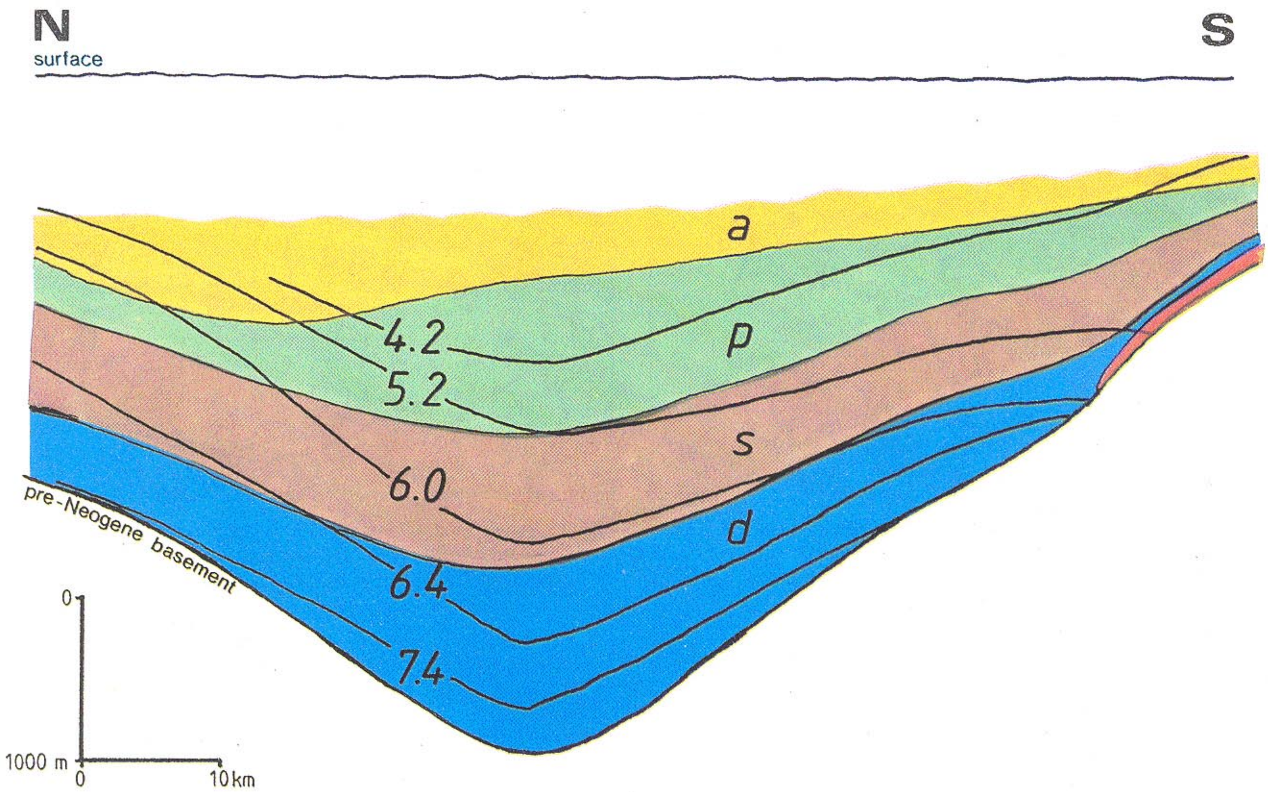

Fig. 4: Facies distribution and numerical datum levels across the Békés basin. Facies were determined by sedimentological method, electrofacies analysis and seismic analysis. Age data were obtained from magnetostratigraphic investigations. Note that datum levels intersect the facies boundaries. Location of profile in Fig. 1.
b: basal conglomerate; d: deep water marl; s: delta front-delta slope deposits; p: delta plain deposits; a: alluvial deposits.

al., 1990; JUHÁSZ & MAGYAR, in press). The conclusions of this study are probably valid in other parts of the basin system as well.

Seismic studies may also facilitate the dating of evolutionary events, as it has been demonstrated for the *Lymnocardium decorum - Prosodacnomya vutskitsi* lineage (MÜLLER & MAGYAR, 1992a, b).

Similarly, it was seismic stratigraphy that provided a key to understanding the continuous southeastward shift of the endemic biota during the Late Neogene. As a consequence of the infilling history outlined above, areals of endemic biota shifted toward southeast, except for a restricted number of marginal taxa which could enter rivers or short living freshwater lakes formed on the alluvial plain. While early species have areals reaching far to the north and northwest, younger, newly evolved ones are - depending on their first appearance datum - restricted to increasingly southern-southeastern areas. This trend can be recognized for all known precursor-descendant relationships in molluscs. Here we give only two illustrations.

The rough geographic distributions of *Lymnocardium conjungens* (M. HÖRNES), *L. penslii* (FUCHS), and *L. schmidti* (M. HÖRNES) are indicated in Fig. 5. The evolutionary relationship of these three forms is documented by surface exposure material in Hungary. While the oldest *L. conjungens* can be found as far north as the Vienna basin and Muntii Oas in Romania, the youngest *L. schmidti* is restricted to the southern and southeastern part of the Pannonian basin, reflecting the shrinking of the lake in time.

A similar change can be followed in the areals of the *Congeria partschi* CZJZEK to *C. rhomboidea* M. HÖRNES lineage. While the Pannonian *C. partschi* group is widespread in the Pannonian basin, the Early Pontian *C. "praerhomboidea"* STEVANOVIĆ is restricted to the southern half of it. The youngest *C. rhomboidea* has an even more limited distribution (Fig. 6).

Thus, the geographic distribution of molluscs is closely interlinked with their stratigraphic position.

From these studies we concluded that new, improved biological chronozonations are needed to describe the stratigraphy of the Pannonian lake sediments. For the moment it seems premature to give a formal proposal for the entire Pannonian and Pontian (concerning the Pontian sensu Stevanović, however, see MÜLLER & MAGYAR, 1992b).

7. CONCLUSIONS

Pannonian to Pontian facies dependence, evolutionary events, and geographical distribution of the endem-

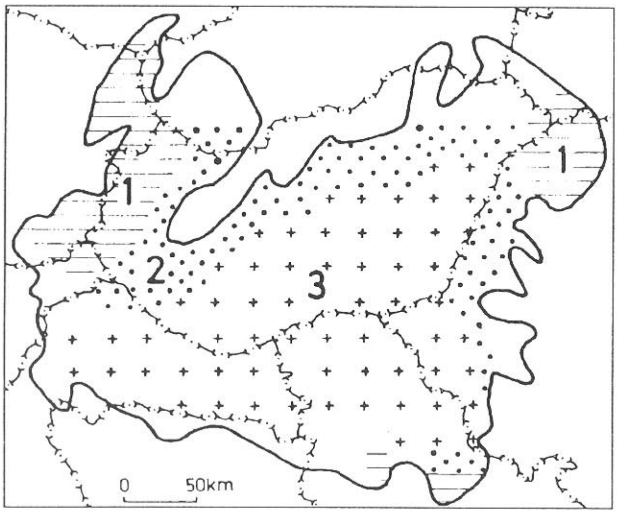

Fig. 5: Rough geographical distribution of the members of the (1) *Lymnocardium conjungens* - (2) *L. penslii* - (3) *L. schmidti* evolutionary lineage in the Pannonian basin. Note the change of areas as a function of time.

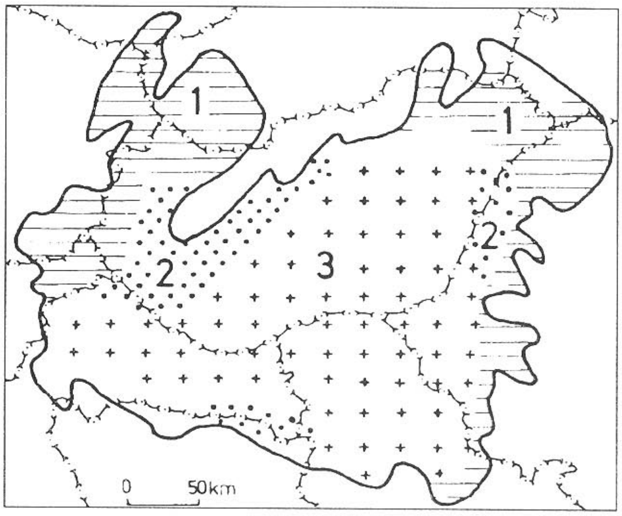

Fig. 6: Rough geographical distribution of the members of the (1) *Congeria partschi* - (2) *C. praerhomboidea* - (3) *C. rhomboidea* evolutionary lineage. Younger forms are more and more restricted to the southern-southeastern part of the Pannonian basin.

ic lacustrine molluscs can be well interpreted within a seismic stratigraphic framework of the Pannonian Basin. All of these three features have important stratigraphic implications. To discern biofacies from biostratigraphic units is essential, because time lines intersect the facies boundaries. Dating of evolutionary events by physical methods allows the establishment of reliable stratigraphic correlation. The geographical distribution of molluscs is closely related to their age, as the fast infilling of the Pannonian basin caused the continuous shrinking of the lake.

Acknowledgment

We thank dr. Györg y Tóth for helping us at the initial steps of comparative study of seismic stratigraphy and biostratigraphy.

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Manuscript received June 15, 1992.
Revised manuscript accepted March 5, 1993.