Geologia Croatica	54/1	15 - 26	11 Figs.			ZAGREB 2001

The Palaeogeography of Lake Pannon During Deposition of the *Congeria rhomboidea* Beds

Sándor **GULYÁS** Jr.

Key words: Molluscs (Bivalve), Index fossil, Palaeobiogeography, Neogene, Late Miocene, Lake Pannon.

Abstract

Lake Pannon covered the area of the Pannonian Basin during the late Miocene. According to the seismic profiles, prograding deltas from the NW and NE resulted in the S-SE migration of the northern palaeoshoreline and the gradual aggradation of the lacustrine basin. The molluscan fauna living in the lake underwent a very rapid evolution. For the younger species, the possibilities of spreading became more and more restricted due to the gradual shoaling of the lake.

The bivalve species *Congeria rhomboidea* M. HÖRNES occurs widely in the Upper Pannonian (Pontian sensu Stevanović) deposits of Hungary and the neighbouring countries. Its evolution is relatively well understood. According to magnetostratigraphic data this species appeared in the lake 8.5 mya. According to the maximal geographical distributions of *C. rhomboidea* and its ancestor *Congeria praerhomboidea* STEVANOVIĆ occurring in sublittoral clay and silt along with the representatives of *Prosodacnomya* coming from littoral and lagoon deposits of the same age the estimated water coverage was around 75,000 km^2 at the time of first emergence of *C. rhomboidea* in the lake. In the north the distribution of *C. praerhomboidea* is strictly restricted to the north of that of *C. rhomboidea*, its descendent, implying a clear S-SE trend in the migration of the lake's northern palaeoshoreline. Distributions of the littoral *Prosodacnomyas* in relation to the sublittoral *C. rhomboidea* of the same age display a similar pattern. Meanwhile the western and southern palaeoshorelines underwent only minor fluctuations.

1. INTRODUCTION

Lake Pannon covered the area of the Pannonian Basin during the Late Miocene. Because of its wide-range distribution, economic importance and unique, mostly "caspi-brackish" endemic biota, its lacustrine deposits have attracted much scientific attention in the past hundred years. According to the latest stratigraphic division accepted for the area and bioprovince of the Western or Central Paratethys these deposits belong to the Pannonian and Pontian chronostratigraphic stages (STEVANOVIĆ et al., 1990; STEININGER et al., 1990) (Fig. 1).

Palaeogeographic and palaeoecologic studies started with the analysis of superficial and shallow borehole lacustrine deposits in the Transdanubian region of Hungary at the beginning of the century (HALAVÁTS, 1902; LŐRENTHEY, 1905). From the 1930's onwards the inner parts of the basin were also studied because of the initiation and development of hydrocarbon prospecting in the areas of the Great Hungarian Plain.

The reliability of any palaeogeographic reconstruction largely depends on the accuracy of the applied stratigraphy. The older palaeogeographical reconstructions were only undertaken on small parts of the lake on the basis of lithostratigraphic and biostratigraphic data. These however, as well as the synthetic reconstructions for larger areas were by no means accurate, as the stratigraphic concept and the sedimentological model underlying them were not without certain ambiguities. According to the traditional Hungarian model based on lithostratigraphic and biostratigraphic division of the lacustrine deposits, the slow deposition of the suspended load from the water of the lake was responsible for the gradual infilling of the lacustrine basin.

Based on abrupt changes in the lithology and the fossil record the age of the lower finer-grained, deepwater deposits was determined to be "Lower Pannonian", while the age of the upper shallow-water, sandy deposits were defined to be "Upper Pannonian" (STRAUSZ, 1941; SZÉLES, 1971) (Figs. 1 and 2). Thus the palaeogeographic maps based on this model were in fact facies maps.

Halaváts (in HALAVÁTS, 1892) referred to an acceptable sedimentation model by noticing the following as early as the end of the last century:

"The Congeria rhomboidea horizon indispensable for the accurate determination of the Pontian stage has been described so far only from the southern parts of Hungary (Austro-Hungary). According to data presented in the collection of the Hungarian Royal Geological Institute and from the literature, localities of this horizon are known only from the Krassó-Szörény Mountains (Muntii Semencului Transylvania) and the hills surrounding the Mecsek Mountains and the city of

University of Szeged, Department of Geology and Paleontology, Egyetem u. 2-6, H-6720 Szeged, Hungary.
e-mail: sanyi@geo.u-szeged.hu, gubanc@yahoo.com

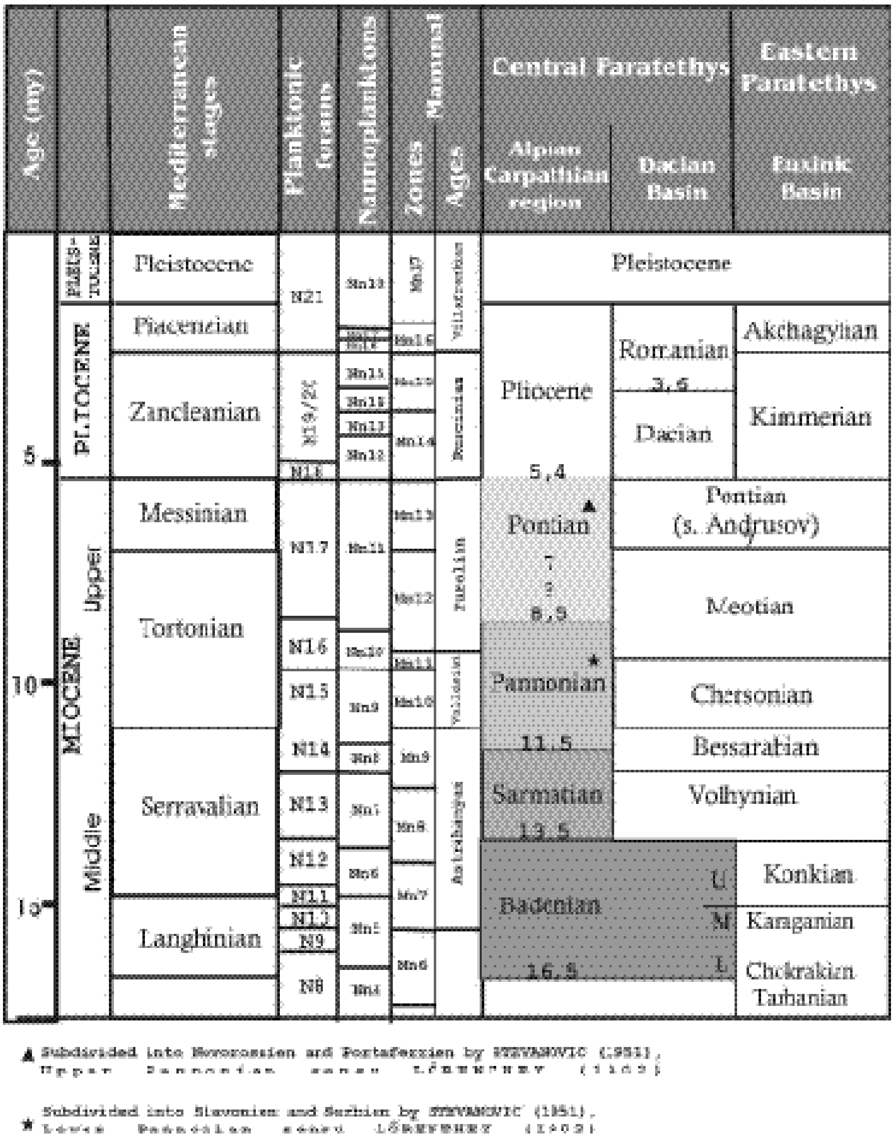

Fig. 1 Chronostratigraphic chart for the areas of the Central and Eastern Paratethys (after STEININGER et al., 1990).

Zagreb. This horizon is totally missing in other parts of the country."

Since the younger Pontian deposits are restricted to the southern parts of former Hungary, the lake must have covered only this part of the country and not the whole Pannonian Basin during the Pontian as the traditional model assumed. However, the recognition of the importance of delta sedimentation in the south-eastern part of the Great Hungarian Plain only brought changes in the traditional sedimentological, stratigraphical and palaeogeographical thinking in the 1970's (MUCSI & RÉVÉSZ, 1975; MAGYAR & RÉVÉSZ, 1976; RÉVÉSZ, 1980; GAJDOS et al., 1983; BÉRCZI & PHILLIPS, 1985). The geometry of progradational delta bodies with the particular facies and subfacies could be clearly identified on the seismic profiles from the inner basin areas (POGÁCSÁS, 1984; POGÁCSÁS & RÉVÉSZ, 1987; MATTICK et al., 1988; JUHÁSZ, 1991) (Figs. 3 and 4).

According to the earlier models the abrupt vertical changes in the fossil record and the lithology of the deposits define horizontal chronohorizons (STRAUSZ, 1971; BARNABÁS & STRAUSZ, 1991; SZÉLES, 1962, 1971). However, seismic research has shown that the isochronous surfaces are inclined towards the center of the basin (Fig. 2), intersecting the horizons marked by boundaries of the bio- and lithofacies (SZALAY & SZENTGYÖRGYI, 1979; POGÁCSÁS & RÉVÉSZ, 1987; HORVÁTH & POGÁCSÁS, 1988; POGÁCSÁS et al., 1988, 1990).

In the past few decades the Hungarian magnetostratigraphic research has undergone significant development (RÓNAY & SZEMETHY, 1979; COOKE et al., 1979; ELSTON et al., 1990), and today a large number of data are readily available for purposes of integrated research (BALOGH & RAKOVITS, 1976; BALOGH & JÁMBOR, 1987; BALÁZS & NUSSZER, 1987). The application of these data onto the seismic profiles shows that Lake Pannon formations are diachronous

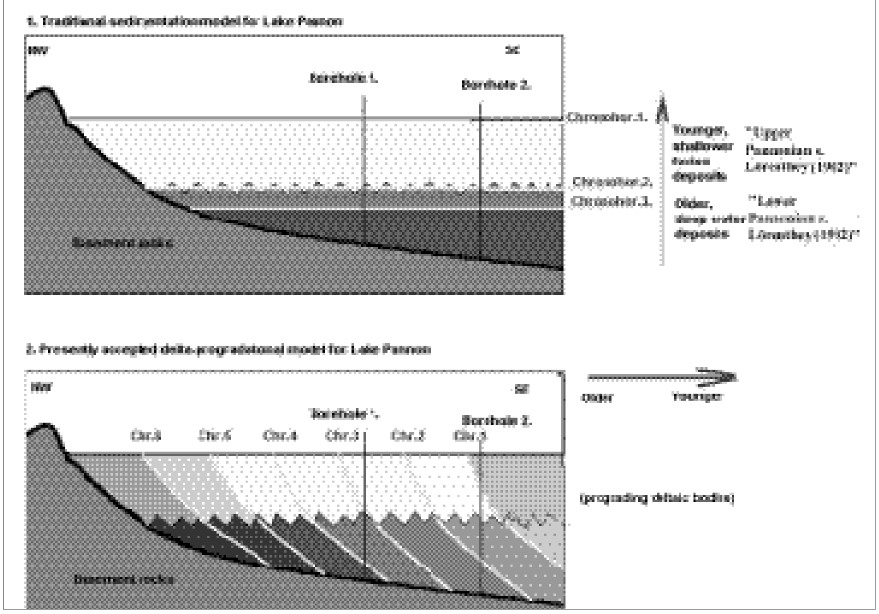

Fig. 2 The sedimentation models for Lake Pannon (GULYÁS, 1998). Deep-water deposits are marked with black and dark grey, while the shallow-water deposits with light grey and white. The differences in the hue indicate changes in the ages of these deposits (lighter ones are younger). It is clearly observable that the isochronous surfaces marking the changes in the surface with time are inclining towards the center of the basin (2 - delta progradational model). In contrast with the traditional model (1), according to which the abrupt changes in the fossil record and the lithological features mark chronohorizons this type of aggradation results in a gradual movement of the facies from the margins towards the center of the basin (2).

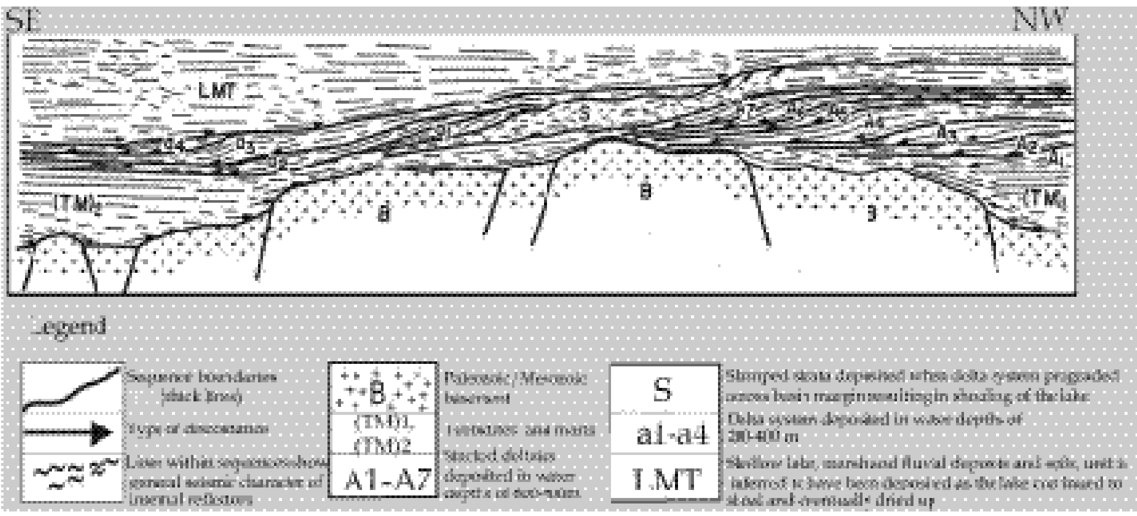

Fig. 3 General configuration of seismic sequences and supersequences in the Pannonian Basin of Hungary (after MATTICK et al., 1988).

(POGÁCSÁS et al., 1988, 1989, 1990; VAKARCS et al., 1994).

Korpásné Hódi (in KORPASNÉ HÓDI et al., 1992) was the first to analyze correlations between the newly defined lithofacies and the occurring biofacies for the area of the Danube-Tisza Interfluve. JUHÁSZ & MAGYAR (1992) extended this type of study to the Tiszántúl area, and suggest that it is possible to characterize certain depositional and deltaic environments by given molluscan assemblages marked by dominant, well-identifiable species (Fig. 5). In this way the biostratigraphic horizons were distinguishable from the biofacies existing in the lake. It also facilitated the chronostratigraphic division of lacustrine deposits in a certain environment or facies by means of analysis of evolutionary lineages of molluscan species (MAGYAR et al., 1999; see Fig. 6).

With the help of these research results it became more and more apparent, that despite the frequent fluctuations in the water level, the infilling of the basin was mainly a uni-directional process. Prograding deltas from the margins resulted in an approximately south-southeast migration of the northern shorelines, and therefore a gradual southward migration of certain facies or depositional environments. As individual environments can be characterized by given molluscan assemblages, the geographical distribution of some molluscan species found in these environments will give a more or less accurate view of the changes in the lake's extension through time. As with the gradual S-

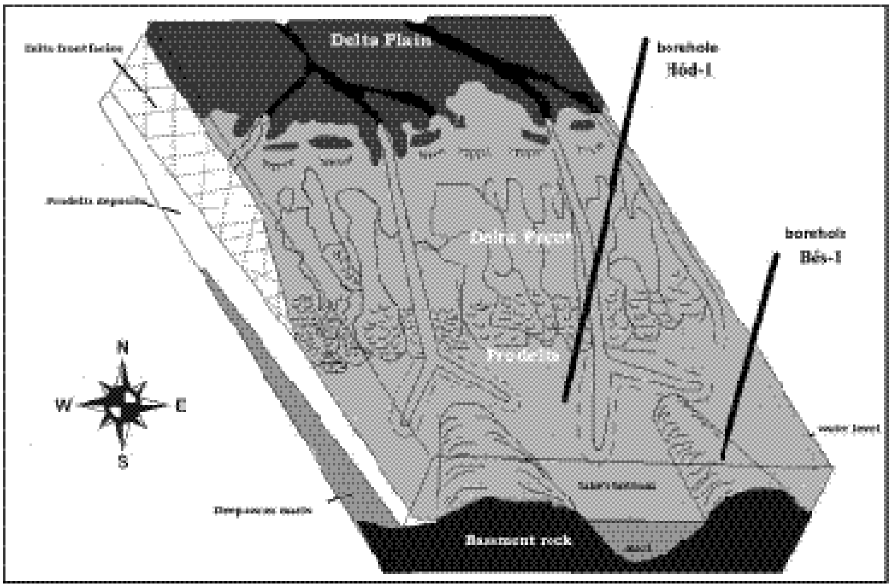

Fig. 4 Idealized view of prograding delta sedimentation and the disribution of sedimentary environments from the SE part of the Pannonian Basin (after BÉRCZI & PHILLIPS, 1985).

SE shoaling of the lake and the migration of the facies, the younger forms of the molluscan species were also restricted to the southern areas of the lacustrine basin.

2. MATERIALS AND METHOD

Palaeogeographic maps based on the new sedimentary model have been based only on magnetostratigraphic and seismic data so far, and only for the area of present-day Hungary (POGÁCSÁS et al., 1993; VAKARCS et al., 1994). The aim of this study was to map the palaeo-shoreline of Lake Pannon for a given moment as accurately as possible using palaeobiogeographic data, and to test the underlying new sedimentary model for the basin.

The bivalve species *Congeria rhomboidea* M. HÖRNES occurs widely in the Upper Pannonian (Pontian sensu STEVANOVIĆ) deposits both in Hungary and in the neighbouring countries of Croatia, Bosnia-Herzegovina, Serbia and Romania as well, which makes it suitable for such investigation (Fig. 8). HALAVÁTS (1892) acknowledged its primary function for age determination when in his own words he "nominated this well-traceable geological horizon after one of its permanently occuring molluscan forms *Congeria rhomboidea* horizon". He placed the age of the horizon into the upper parts of the then accepted Upper Pontian stage.

The first illustrated description of the bivalve species *Congeria rhomboidea* M. HÖRNES was published in a work entitled "Die fossilen Mollusken der

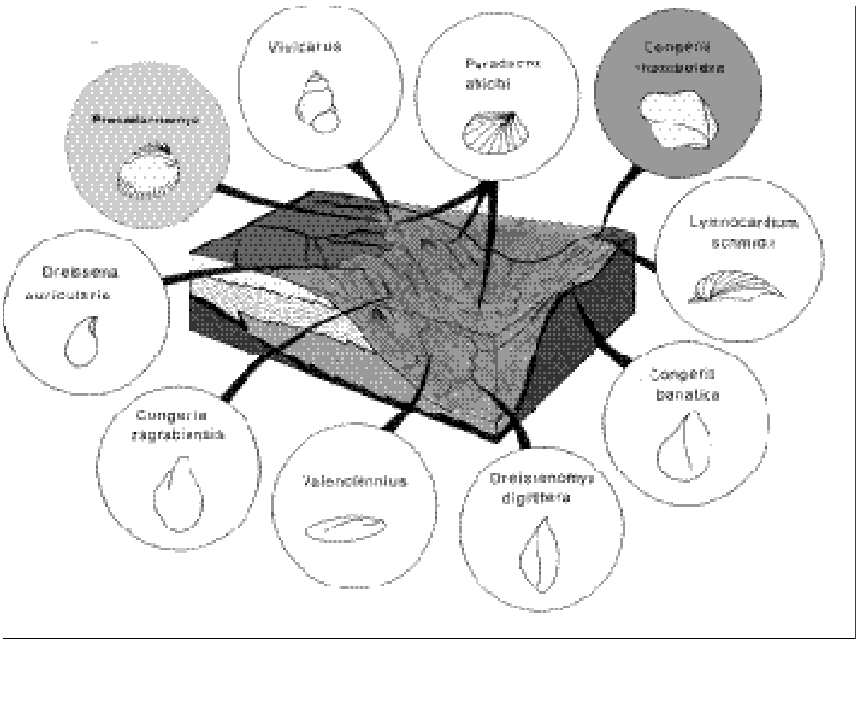

Fig. 5 Characteristic molluscan assemblages marked by dominant species in relation to depositional environments (after JUHÁSZ & MAGYAR, 1992). Note the assemblages marked by *Congeria rhomboidea* M. HÖRNES and *Prosodacnomya*.

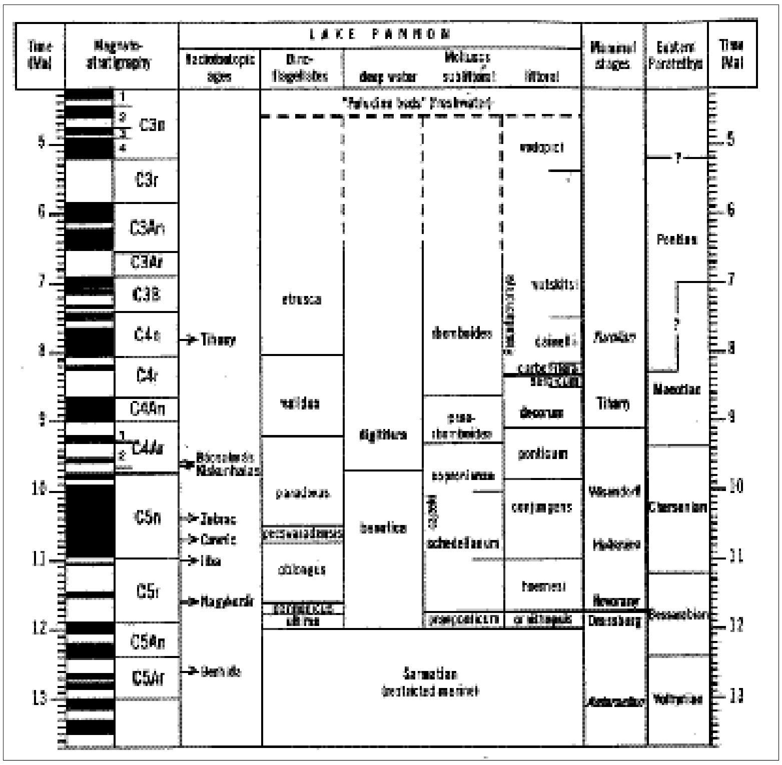

Fig. 6 Integrated correlation chart for the Lake Pannon deposits (after MAGYAR et al., 1999). Note that according to the chart the base of the Pontian (8.5 mya) is 1-1.5 my. older in the area of Lake Pannon than in the Eastern Parathetys.

Tertiaeren Becken von Wien II" by M. HÖRNES (1855). The type locality of this species is Árpád (today Nagyárpád, a part of the city of Pécs) in Hungary. It also appears outside the Pannonian Basin (ANDRUSOV, 1897, 1909; HOERNES, 1901; WENZ, 1942).

Several theories concerning the origin and the evolutionary lineage of this species have come to light since the second half of the 19th century. Most authors were looking for relative forms of this species outside the Pannonian Basin (ANDRUSOV, 1897, 1909; HOERNES, 1901; WENZ, 1942). Stevanović was the first to point to a very important factor in the palaeogeography of Lake Pannon and the Paratethys to underlie his phylogenetic concept of *Congeria rhomboidea* M. HÖRNES (STEVANOVIĆ, 1961, 1978).

The Pannonian basin evolved during the Miocene period. The Late Miocene belongs to the post-rift phase of basin evolution accompanied by isostatic thermal subsidence due to the thinning and cooling of the lithosphere following the rifting process (KÁZMÉR, 1990; ROYDEN et al., 1983). During the Miocene, connection of the Central Paratethys with the Mediterranean and the Indo-Pacific Ocean was repeatedly opened and closed (RÖGL & STEININGER, 1983). The final isolation of the Central Paratethys commenced in the beginning of the Late Miocene (STEININGER et al., 1988). The Attic phase of the Alpine orogeny in the Southern Carpathian Mountains isolated the water masses covering the Pannonian Basin from the rest of Parathetys from as early as the Bessarabian until the beginning of the Pontian (13.5-8.5 my), i.e. during the whole Pannonian. In the Sarmatian this resulted in the creation of miohaline, "brackish" and later on in the Pannonian and Pontian oligohaline, "caspi-brackish" conditions in the lake. These factors induced the evolution of an endemic molluscan biota bearing unique features. During the Early Pontian, the connection between the Pannonian and Dacian Basins was restored by means of a waterway formed near the present Iron Gate: the Đerdap or Porta Ferra Strait. Across this strait the eurytropic species, which had evolved in the Pannonian Basin could have migrated eastward into the Dacian-Euxinic Basins. Consequently, this species emerged and developed in the Pannonian Basin and migrated eastward following the restoration of the connections of waterways at a later stage (STEVANOVIĆ, 1961, 1978).

The evolution of *Congeria rhomboidea* M. HÖRNES is now relatively well-understood. The gradual evolution of *Congeria rhomboidea* M. HÖRNES from *Congeria zsigmondyi* and a relation with *Congeria partschi* seems to be well-traceable in the Pannonian Basin through a number of transitional forms with gradual changes in the shell morphology. From the bivalve species *Congeria zsigmondyi* or a certain type of it ("semiptera") a strongly convex form with a high shell develops ("praerhomboidea"). Then on this form a strong second rib appears ("dubocaensis"), and finally the size of the shell increases ("rhomboidea") reaching an extreme rate in the final stage of development ("dilatata") (Fig. 7).

This gradual change in the shell's morphology occurs in such a way that there is an extraordinary variety at all levels, so the names represent only certain stages of the evolution. Because *Congeria rhomboidea*

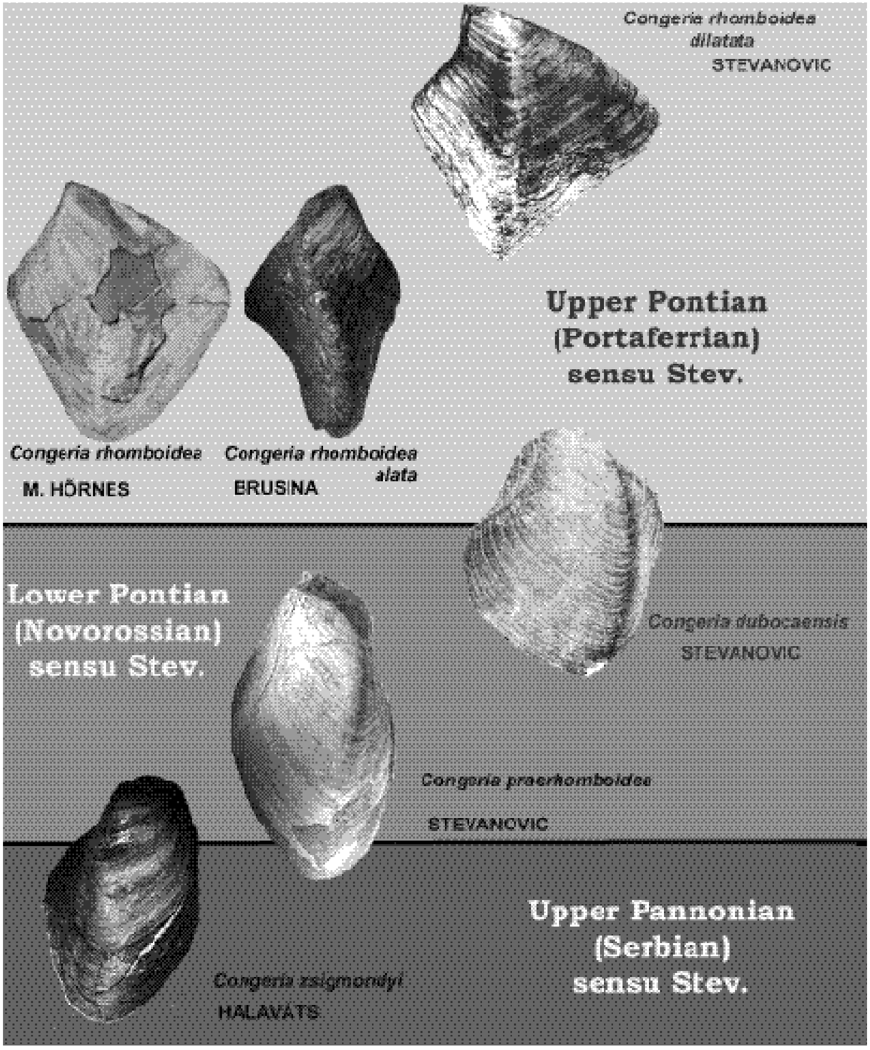

Fig. 7 The evolutionary lineage of *Congeria rhomboidea* M. HÖRNES (after STEVANOVIĆ, 1978).

M. HÖRNES exhibits an almost continuous development with hardly distinguishable stages or forms, it is very hard to define the area of its distribution in the lake without knowing how to define the species itself.

In this study the form "dubocaensis" is considered to be the very first representative of the species *Congeria rhomboidea* M. HÖRNES on the basis of the morphological feature noticed even by LŐRENTHEY (1905) while he was tracing the lineage between *C. triangularis* and *C. rhomboidea*; i.e. the appearance of the second strong rib on the shell to define the species.

According to magnetostratigraphic data this bivalve species appeared in the lake approximately 8.5 million years ago (Fig. 6). Thus its geographical distribution will give us a more or less accurate view about the extension of the lake at this time.

A distributional database has been set up from 77 pieces of literature dealing with the Pannonian and the Pontian. Additional data comes from collections at the University of Szeged (JATE), University of Budapest (ELTE), the Hungarian Geological Institute and the University of Debrecen (KLTE) as well as from the Hungarian Oil and Gas Company (MOL Rt.) (see GULYÁS, 1998 for details). Data had been applied to maps with a scale of 1:600,000, which were reduced afterwards.

The geographical distributions of the bivalve species *Congeria praerhomboidea* STEVANOVIĆ and the representatives of the *Prosodacnomya* genera have also been applied onto maps as a complementary and verificatory check, as *Congeria praerhomboidea* STEVANOVIĆ is the direct ancestor of *Congeria rhomboidea* M. HÖRNES. According to the delta progradation model the geographical distribution of this species was expected to be restricted northward of that of *Congeria rhomboidea* M. HÖRNES. *Congeria rhomboidea* M. HÖRNES comes primarily from sublittoral deposits - clay and silt. Thus its distribution will mark the borderline of the sublittoral facies in the lake. In addition the distribution of the representatives of the *Prosodacnomya* genus of the same age coming from littoral deposits will show the incidence of the littoral facies and the gradually freshening lagoons at the same time.

3. RESULTS AND DISCUSSION

The constructed palaeobiogeographic map (Fig. 8) displays the geographical distributions of *Congeria rhomboidea* M. HÖRNES and *Congeria praerhomboidea* STEVANOVIĆ with 192 data points as well as the distribution of localities with representatives of the *Prosodacnomya* genus (310 data points). The larger signs indicate general localities like "the northern slope of Majevica Mt." for example.

The scarcity of dots on the map in certain areas is due to lack of information because of an insufficient number of boreholes in the area, or the lack of a continuous data record on sublittoral facies deposits, rather than real rarity of the species. Conversely, in other areas where many dots are displayed on the map, this does not necessarily imply that more animals must have existed. Rather these dots indicate the distribution of localities with surface outcrops, where there is easy access to these fossil-bearing layers. Thus lots of data can be found in these areas.

The created palaeobiogeographic map records the outcome of complex processes, which had been going on for millions of years in the lake, and do not represent one single moment in the lake's history. As the northern shoreline migrated to the S-SE with the continuos shoaling of the lake, the littoral and sublittoral facies shifted with the passage of time. Consequently, for example the specimen of the *Prosodacnomya* genus found at Lake Balaton might be even millions of years older than the one from Battonya, South-east Hungary. In order to draw the boundaries of a given facies marked by the geographical distributions of specimens of *Congeria rhomboidea* M. HÖRNES or the *Prosodacnomya* genus, the maximal area of their distribution had to be considered by taking into account their marginal occurrences. These will more or less accurately give the boundary of the facies at that time, when this species or genus first appeared in the lake.

Maps (Figs. 9 and 10) were created by considering the maximal areas of distribution for the species *Congeria rhomboidea* M. HÖRNES, *Congeria praerhomboidea* STEVANOVIĆ and the genus *Prosodacnomya*. These will represent the boundaries of the sublittoral facies marked by *Congeria rhomboidea*, and the littoral facies marked by *Prosodacnomya* at the time the bivalve species *Congeria rhomboidea* M. HÖRNES first emerged in the lake - 8.5-8.6 mya (Fig. 6). With

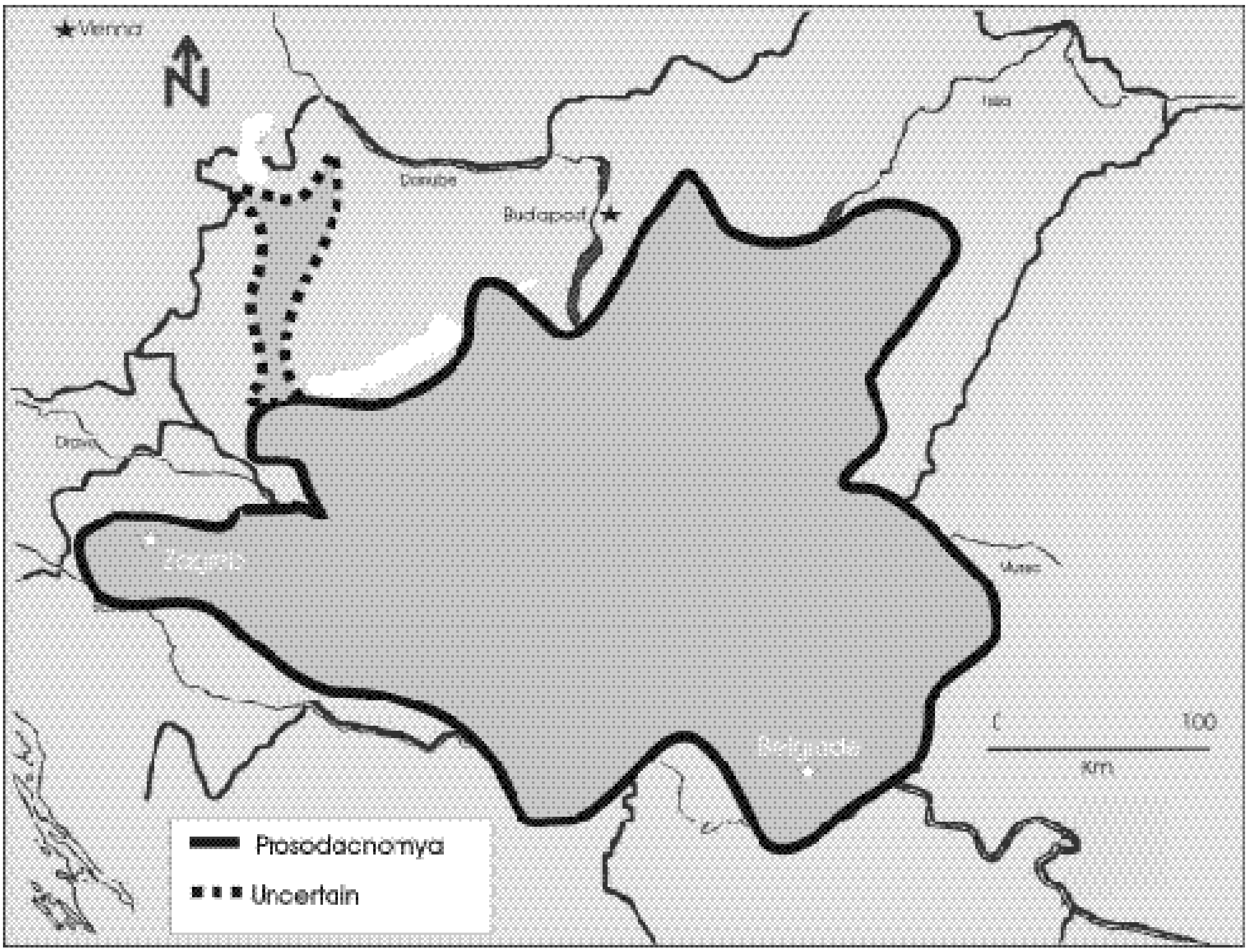

Fig. 8 The geographical distributions of *Congeria rhomboidea* M. HÖRNES, *Congeria praerhomboidea* STEVANOVIĆ and *Prosodacnomya* in the Pannonian Basin.

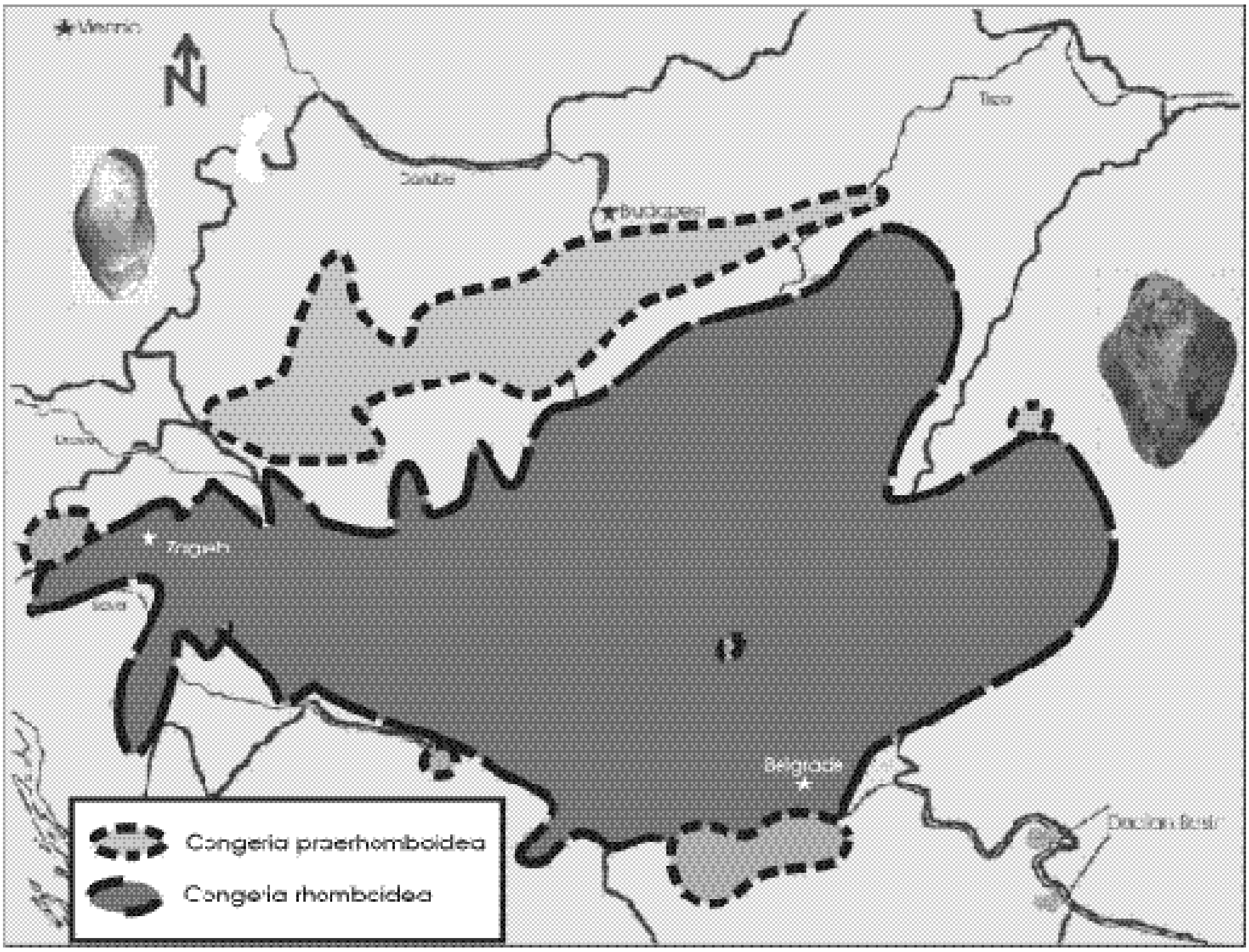

Fig. 9 Maximum areas of distribution for *Congeria rhomboidea* M. HÖRNES and *Congeria praerhomboidea* STEVANOVIĆ. Note that on the northern part of the Pannonian basin the distribution of *Congeria praerhomboidea* STEVANOVIĆ is restricted to the north of the maximum distribution area of *Congeria rhomboidea* M. HÖRNES, indicating a continuous unidirectional S-SE migration of the palaeoshoreline there. Meanwhile on the southern part the two areas tend to overlap at some places indicating only minor fluctuations in the position of the shoreline.

the combinations of these two maps a new palaeogeographic map has been set up with the palaeoshorelines and the roughly estimated boundaries of the two facies in the lake for a given moment (Fig. 11).

On the basis of data presented on the map a water coverage of roughly 75,000 km^2 has been calculated. The path of the lake's northern shoreline seems to correspond to the line of the 8.2 million year chronoboundary on the map prepared by VAKARCS et al. (1994) on the basis of seismic and magnetostratigraphic data. Therefore the results of the two methods seem to correspond well, underlying the accuracy of the new delta progradational model. However, the accuracy of the age determination of VAKARCS et al. (1994) on their map remain questionable (8.2 mya vs. 8.5 mya).

The littoral and lagoonal zones marked by the *Prosodacnomya* are mainly restricted to the northern areas of the lake situated roughly north of the line of Hrvatsko Zagorje (Northern Croatia) - Mecsek Mts. (Southwest-Hungary) - Paks (on the bank of the Danube in South-Hungary) - Egyek (North-eastern Hungary) (Fig. 11). At the same time in the southern Slovenian, Croatian, Bosnian and Serbian parts sublittoral and deep-water environments existed in the lake. In some parts in the centre of the lake and on the south-eastern and south-western marginal areas *Congeria rhomboidea* M. HÖRNES occurs together with *Prosodacnomya* in the localities of Beočin, Serbia (STEVANOVIĆ et al., 1990), an area between the rivers of Sava and Majevica, Northern Bosnia (STEVANOVIĆ et al., 1990), Hrvatsko zagorje, Croatia (BASCH & ŽAGAR-SAKAČ, 1992) (Figs. 9 and 10). *Congeria rhomboidea* M. HÖRNES appears in a lower position in sublittoral deposits in the sequences, while the representatives of *Prosodacnomya* occur in the overlying younger littoral deposits. Similarly in the southern areas - Posavo-Tamnava, Kolubara Basin, Mislodjin, Bodarevac, Bučje and Beočin, Southern Serbia (STEVANOVIĆ, 1951; STEVANOVIĆ et al., 1990) - the older *Congeria praerhomboidea* STEVANOVIĆ and the younger *Congeria rhomboidea* M. HÖRNES occur in the same localities, but in different stratigraphic levels (Figs. 8 and 9). These imply that there were no significant and permanent changes in the position of the shoreline in these south-

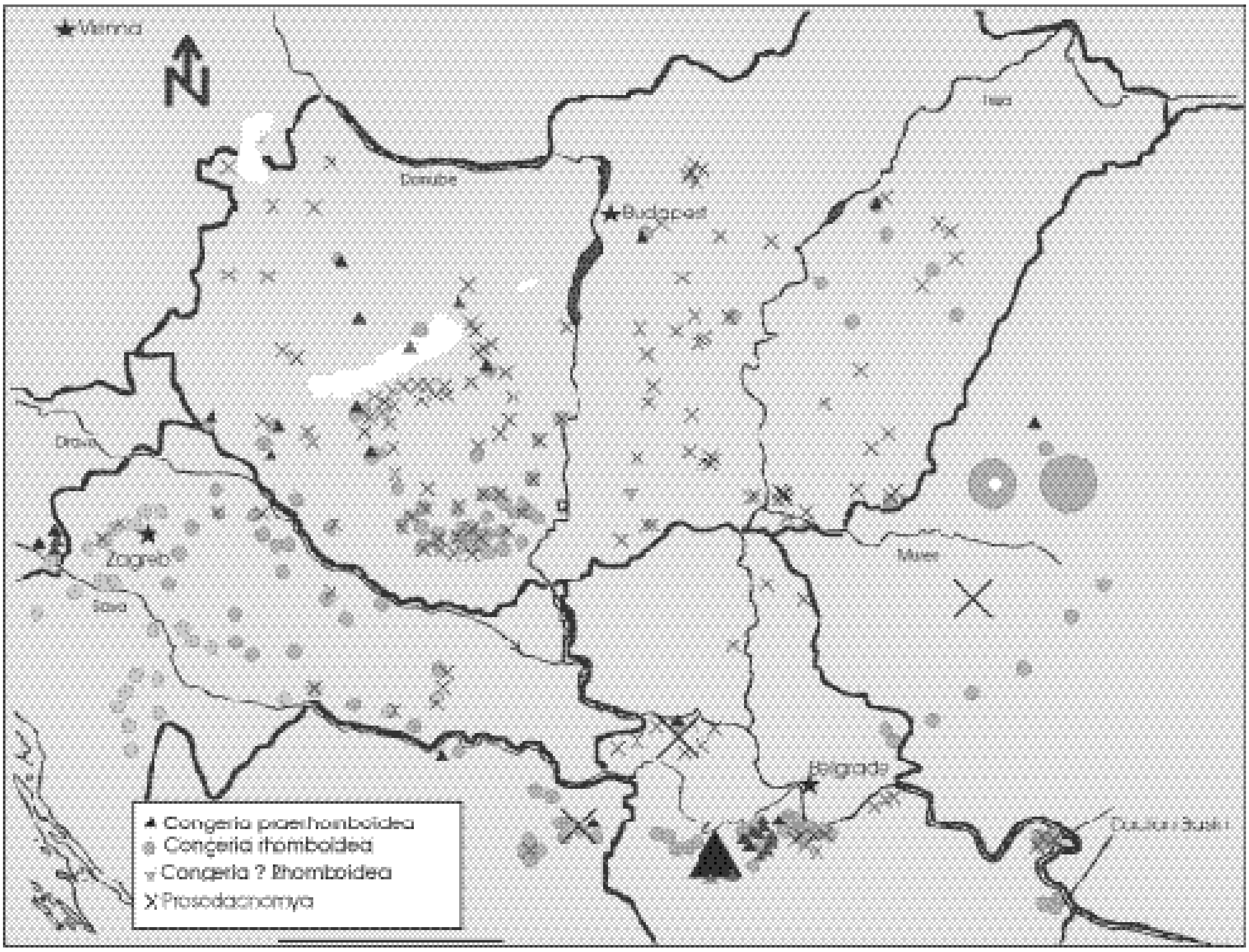

Fig. 10 Maximum area of distribution of the *Prosodacnomya* genus. Dotted line indicates uncertainty in the water coverage for the area of Kisalfld.

ern areas. Only minor fluctuations can be observed, and the shoreline seems to have always returned to its original position. On the northern, eastern and western margins of the lake however, the fact that the littoral representatives of *Prosodacnomya* and the older *Congeria praerhomboidea* are restricted strictly north of the area of distribution of *Congeria rhomboidea* M. HÖRNES implies a steady, gradual migration of the shoreline towards the S-SE. The collective appearance of *Congeria rhomboidea* M. HÖRNES and *Congeria praerhomboidea* STEVANOVIĆ in some areas, e.g. Táska, Mezőcsokonya, Kőbánya, Nyárád - Hungary (Fig. 8), might represent transitional forms or possibly be wrong determinations, e.g. for Nyárád (MAGYAR, pers. comm.).

The water coverage assumed by the presence of littoral *Prosodacnomyas* in the alluvial plain areas near Sopron, and the Kisalföld, Northwestern Hungary are highly questionable (Fig. 10 - dotted line area), and this region was not considered to be a part of the lake's area on the final map (Fig. 11). Fossils coming from these areas are very hard to determine due to poor preservation, and the majority of them are lost. Specimens collected by István Vitális can be found in the Hungarian Natural History Museum, though the single *Prosodacnomya* from Sopron is missing. There are three major ways of interpreting these data. First it could be assumed that all the fossil descriptions are incorrect, so there were no *Prosodacnomyas* existing in this area. Alternately, the lake managed to occupy the alluvial plain area of the Kisalföld for a very short time, so it seems to be acceptable to have some localities with *Prosodacnomya* there. Or perhaps the *Prosodacnomya* was capable of adapting to fresh-water alluvial conditions, so its areal distribution did not correspond to the changes in the lake's water coverage. Further investigation is required to clarify this problem.

4. CONCLUSION

Results of this palaeobiogeographic study seem to corroborate sedimentation hypotheses based on seismic, magnetostratigraphic and sedimentological data for Lake Pannon, implying a clear S-SE migration of the northern palaeoshorelines and depositional environments. This indicates two major applications of palaeontologic and palaeobiogeographic methods. First, the utilization of an integrated multidisciplinary approach, embedding palaeontological data, gives more reliable

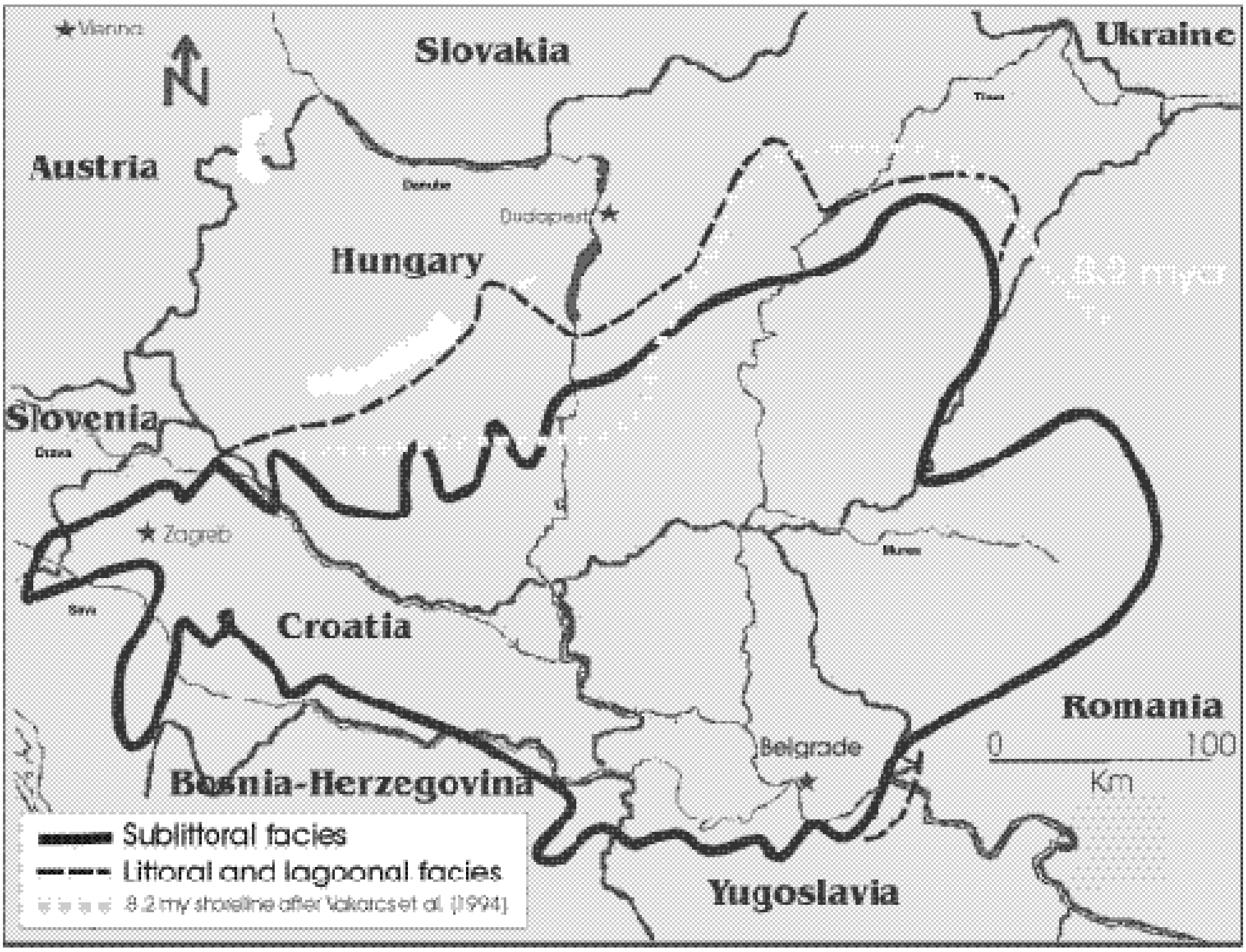

Fig. 11 The palaeogeographic view of Lake Pannon 8.5 mya based on palaeobiogeographic data.

and accurate results. It also seems to be the only relevant tool in settling the controversies surrounding the stratigraphic subdivison and correlation of Lake Pannon deposits.

Secondly, the majority of petroleum displays are connected to certain depositional environments. Studies such as this may help petroleum exploration by tracing the migration and geographic distribution of depositional environments significant from the point of reservoir and source potential through time in a basin on a purely palaeontological, palaeoecological basis.

Acknowledgements

The author wishes to express his acknowledgements to the following persons: Dr. Miklós Szónoky at the Department of Geology and Palaeontology at JATE University of Szeged; colleagues at Geologia Croatica (Zagreb) for making this publication possible, especially to Dr. Igor Vlahović and Mr. Oto Basch for their help in the identification of Croatian localities; Dr. Pál Sümeghy and Dr. Miklós Kozák (KLTE), Dr. András Galácz (ELTE) and Dr. Pál Müller and Dr. László Kordos (MÁFI) for giving access to the palaeontological collections. Thanks to the colleagues of the palaeobiology and palaeontology group of the Department of Geology and Geophysics at the University of Wisconsin, Madison, for their help in reviewing and commenting on the manuscript.

Finally to Dr. Imre Magyar (MOL Rt.) for initiating and fully supporting this work. This work has been partly supported by NSF Grant EAR 9706230 and National Science Research Foundation (OTKA) Grant T/029342.

5. REFERENCES

ANDRUSOV, N.I. (1897): Iszkopajemüje i zsivuscsije Dressenidae Evrazii.- Otd. Geol. i min. esestv. Tr. Spb. Ops., 25, 100, St. Petersburg.

ANDRUSOV, N.I. (1909): Kriticseszkie Zametki o Ruszkom Neogene 2.: Gorizont sz C. subrhomboidea v kamüsvurunszkom profile obsz Jesztyesztrojszp.- Otd. Geol. i min. esestv. Tr. Spb. Ops., 2, 155, Kiev.

BALÁZS, E. & NUSSZER, A. (1987): Magyarország medenceterületeinek kunsági (pannóniai s. str.) emeletbeli vulkanizmusa.- A Magyar állami Földtani Intézet Évkönyve, 69, 95-113, Budapest.

BALOGH, K. & JÁMBOR, Á. (1987): A magyarországi kunsági (pannóniai s. str.) emeletbeli képzõdmények idõbeli helyzetének meghatározása.- A Magyar állami Földtani Intézet Évkönyve 69, 27-36, Budapest.

BALOGH, K. & RAKOVITS, Z. (1976): ÉK-Magyarország néhány miocén vulkanitjának K-Ar kora.- A Magyar állami Földtani Intézet Évi jelentése az 1974. évrõl, 471-476, Budapest.

BARNABÁS, K. & STRAUSZ, L. (1991): A délnyugat-dunántúli pannónikum - Földtani Közlöny, 119,191-306, Budapest.

BASCH, O. & ŽAGAR-SAKAČ, A. (1992): Dreissenidae (Mollusca, Lamellibranchiata) pontskog kata u Hrvatskoj.- Acta Geol., 22, 1-96, Zagreb.

BÉRCZI, I. & PHILLIPS, R.L. (1985): Processes and depositional environments within Neogene deltaic-lacustrine sediments, Pannonian Basin, Southeastern Hungary.- Geophysical Transactions, 31, 71-87.

COOKE, H.B.S., HALL, J.M. & RÓNAY, A. (1979): Palaeomagnetic, sedimentary and climatic records from boreholes at Dévaványa et Vésztõ, Hungary.- Acta Geologica Hungarica, 22, 89-109, Budapest.

ELSTON, D.P., LANTOS, M. & HÁMOR, T. (1990): Az Alföld pannóniai (s.l.) képzõdményeinek magnetosztratigráfiája.- A Magyar állami Földtani Intézet Évi Jelentése az 1988. évrõl, 109-134, Budapest.

GAJDOS, I., PAPP, S., SOMFAI, A. & VÖLGYI, L. (1983): Az alföldi pannóniai (s.l.) képzõdmények litosztratigráfiai egységei.- Magyar állami Földtani Intézet , 70, Budapest.

GULYÁS, S. (1998): A Pannon-tó õsföldrajzi képe a *Congeria-rhomboideás* rétegek lerakódása idején.- Unpublished M.Sc. Thesis, University of Szeged, 130 p., Szeged.

HALAVÁTS, Gy. (1892): Õslénytani adatok Délmagyarország neogén korú üledékei faunájának ismeretéhez. VI. A királykegyei pontusi korú fauna.- A Magyar Királyi Földtani Intézet Évkönyve, 10, 25-41, Budapest.

HALAVÁTS, Gy. (1902): A balatonmelléki pontusi korú rétegek faunája.- In: LŐRENTHEY, I. (ed.): A Balaton tudományos tanulmányozásának eredményei 1/1 õslénytani Függelék 4/2. 1-74, Budapest.

HOERNES, R. (1901): Congeria oppenheimi und hilberi.- Sitz. d. math.-nat. kl. d. k. Akad. d. Wiss., Bd.110.A.I., 228, Wien.

HORVÁTH, F. & POGÁCSÁS, Gy. (1988): Contribution of seismic reflection data to chronostratigraphy of the Pannonian Basin.- In ROYDEN, L.H. & HORVÁTH, F. (eds.): The Pannonian basin. A study in basin evolution. AAPG Memoir, 45, 97-105, Tulsa, Budapest.

HÖRNES, M. (1855): Die fossilen Mollusken der Tertiaeren Becken von Wien II.- Th. -Abh. d. k. k. g. R.-A., Bd. 4, 364-365, Wien.

JUHÁSZ, Gy. (1991): Lithostratigraphical and sedimentological framework of the Pannonian (s.l.) sedimentary sequence in the Hungarian Plain (Alföld), Eastern Hungary.- Acta Geologica Hungarica, 34, 53-72, Budapest.

JUHÁSZ, Gy. & MAGYAR, I. (1992): A pannóniai s.l. lithofáciesek és molluszka-biofáciesek jellemzése és korrelációja az Alföldön.- Földtani Közlöny, 122/2-4,167-194, Budapest.

KÁZMÉR, M. (1990): Birth, life and death of the Pannonian lake.- Palaeogeography, palaeoclimatology, palaeoecology, 79, 171-188, Amsterdam.

KORPASNÉ HÓDI, M., POGÁCSÁS, Gy. & SIMON, E. (1992): Palaeogeographic outlines of the Pannonian s.l. of the southern Danube-Tisza interfluve.- Acta Geologica Hungarica, 35, 145-163.

LŐRENTHEY, E. (1902): Die pannonische fauna von Budapest.- Palaeontographica, 48, 137-295.

LŐRENTHEY, I. (1905): Adatok a Balaton melléki pannóniai korú rétegek faunájához és stratigráfiai helyzetéhez.- In: LŐRENTHEY, I. (ed.): A Balaton tudományos tanulmányozásának eredményei 1/1 õslénytani Függelék, 4/3, 1-193, Budapest.

MAGYAR, I., GEARY, D., SÜTÕ-SZENTAY, M., LANTOS, M. & MÜLLER, P. (1999): Integrated bio-, magneto and chronostratigraphic correlations of the Late Miocene Lake Pannon deposits.- Acta Geologica Hungarica, 42/1, 5-31.

MAGYAR, L. & RÉVÉSZ, I. (1976): Data on the classification of Pannonian sediments of the Algyõ area.- Acta Mineralogica Petrographica, 22, 267-283, Szeged.

MATTICK, R.E., PHILLIPS, R.L. & RUMPLER, J. (1988): Seismic stratigraphy and depositional framework of sedimentary rocks in the Pannonian basin in southeastern Hungary. - In: ROYDEN, L.H. & HORVÁTH, F. (eds.): The Pannonian Basin. A study in basin evolution. AAPG Memoir, 45 , 117-145, Tulsa, Budapest.

MUCSI, M. & RÉVÉSZ, I. (1975): Neogene evolution of the southern part of the Great Hungarian Plain on the basis of sedimentological investigations.- Acta Mineralogica Petrographica, 22, 29-49, Szeged.

POGÁCSÁS, Gy. (1984): Results of seismic stratigraphy in Hungary.- Acta Geologica Hungarica, 27, 91-108.

POGÁCSÁS, Gy. & RÉVÉSZ, I. (1987): Seismic stratigraphic and sedimentological analysis of Neogene delta features in the Pannonian basin.- A Magyar állami Földtani Intézet Évkönyve, 70, 267-273, Budapest.

POGÁCSÁS, Gy., LAKATOS, L., UJSZÁSZI, K., VAKARCS, G., VÁRKONYI, L., VÁRNAI, P. & RÉVÉSZ, I. (1988): Seismic facies, electro-facies and Neogene sequence chronology of the Pannonian basin.- Acta Geologica Hungarica, 31, 175-207.

POGÁCSÁS, Gy., JÁMBOR, Á., MATTICK, R.E., ELSTON, D.P., HÁMOR, T., LAKATOS, L., LANTOS, M., SIMON, E., VAKARCS, G., VÁRKONYI, L. & VÁRNAI, P. (1989): A nagyalföldi neogén képzõdmények kronosztratigráfiai viszonyai szeizmikus és palaeomágneses adatok összevetése alapján.- Magyar Geofizika, 30, 41-62, Budapest.

POGÁCSÁS, Gy., MÜLLER, P. & MAGYAR, I. (1990): Seismo and biostratigraphy of the Late Neogene deposits in Hungary.- 9th Congress of Regional Committee on Mediterranean Neogene Stratigraphy, Abstracts, 271-272, Budapest.

POGÁCSÁS, Gy., MÜLLER, P. & MAGYAR, I. (1993): The role of seismic stratigraphy in understanding biological evolution in the Pannonian Lake (SE Europe, Late Miocene).- Geol. Croat., 46/1,63-69.

RÉVÉSZ, I. (1980): Az Algyõ-2 telep földtani felépítése, üledékföldtani heterogenitása és õsföldrajzi viszonyai.- Földtani Közlöny, 110, 512-539, Budapest.

RÓNAY, A. & SZEMETHY, A. (1979): Az Alföld-kutatás újabb eredményei. Palaeomágneses vizsgálatok laza üledékeken.- A Magyar állami Földtani Intézet Évi jelentése az 1977. Évrõl, 67-84, Budapest.

ROYDEN, L., HORVÁTH, F., NAGYMAROSI, A. & STEGENA, L (1983): Evolution of the Pannonian Basin system. 2. Subsidence and thermal history.- Tectonics, 2, 91-137.

RÖGL, F. & STEININGER, F.F. (1983): Vom Zerfall der Tethys zu Mediterran und Paratethys. Die Neogene Palaeogeographie und Palinspatik des zirkum-mediterranen Raumes.- Ann. Naturhist. Mus. Wien, 85, 135-163, Wien.

STEININGER, F.F., MÜLLER, C. & RÖGL, F. (1988): Correlation of Central Paratethys, Eastern Paratethys and Mediterranean Neogene Stages.- In: ROYDEN, L.H. & HORVÁTH, F. (eds.): The Pannonian Basin. A Study in Basin Evolution. AAPG Memoir, 45, 79-87, Tulsa, Budapest.

STEININGER, F.F, BERNOR, R.L. & FAHLSBUSCH, V. (1990): European Neogene marine/continental chronologic correlations.- In: LINDSAY, E.H, FAHLBUSCH, V. & MEIN, P. (eds.): European Neogene Mammal Chronology, Plenum, 135-180, New York.

STEVANOVIĆ, P.M. (1951): Pontische stufe im engeren sinne - Obere Congerienschichten Serbiens und der angrenzenden Gebiete.- Serbische Akademie der Wissenschaften, Sonderausgabe 187, Matematisch-Naturwissenschaftliche Klasse, 1-351, Beograd.

STEVANOVIĆ, P.M. (1961): Pontische fauna mit Limnocardium Petersi bei Kadar an der Save (Nord Bosnien).- Annalés Geologiqués da la Péninsulé Balkanique, 28, 177-216, Beograd.

STEVANOVIĆ, P.M. (1978): Neue pannon-pontische mollusken arten aus Serbien.- Annales Geologiques de la Péninsulé Balkanique, 42, 315-344, Beograd.

STEVANOVIĆ, P.M., NEVESSKAYA, L.F. MARINESCU, A., SOKAČ, A. & JÁMBOR, Á. (eds.) (1990): Chronostratigraphie und Neostratotypen. Neogen der Westliche ("Zentrale") Parathetys. 8. Pontien.- JAZU-SANU, Zagreb-Beograd, 952p.

STRAUSZ, L. (1941): A Dunántúli pannon szintezése.- Földtani Közlöny, 71, 220-237, Budapest.

STRAUSZ, L. (1971): Pannóniai emelet (pliocén).- Földtani Közlöny, 101, 114-119, Budapest.

SZALAY, A. & SZENTGYÖRGYI, K. (1979): Adatok a szénhidrogénkutató fúrások által feltárt medencebeli pannon képzõdmények litológiai tagolódásának ismeretéhez trendelemzés alapján.- Az MTA 10. Oszt. Közleményei, 12, 401-423, Budapest.

SZÉLES, M. (1962): Alsópannóniai medenceüledékek puhatestû faunája.- Földtani Közlöny, 92, 53-60, Budapest.

SZÉLES, M. (1971): A Nagyalföld medencebeli pannon képzõdményei.- In: GOCZAN, F. & BENKÕ, J. (eds.): A magyarországi pannon kori képzõdmények kutatásai. Akadémiai Kiadó , 253-344, Budapest.

VAKARCS, G., VAIL, P.R., TARI, G., POGÁCSÁS, Gy., MATTICK, R.E. & SZABO, A. (1994): Third order Middle Miocene-Early Pliocene depositional sequences in the prograding delta complex of the Pannonian Basin.- Tectonophysics, 240, 81-106.

WENZ, W. (1942): Die Mollusken des Pliozans der rumanische erdölgebiete.- Senckenbergiana, 24, 116-117.

Manuscript received March 23, 2000.

Revised manuscript accepted April 23, 2001.