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MIOCENE EVOLUTION OF SEDIMENTARY ENVIRONMENTS AND PALEOGEOGRAPHIC RELATIONS OF PANNONIAN (CARPATHIAN) BASIN

ABSTRACT: KORPÁS-HÓDI M. & BOHN-HAVAS M., *Miocene evolution of sedimentary environments and paleogeographic relations of Pannonian (Carpathian) Basin.* (IT ISSN 0391-9838, 1998).

The Miocene development of the Pannonian (Carpathian) basin is related to the collision of the European and African plates. The Alps and the Carpathians uplifted in the Miocene and, due to the arising extensional forces, in the area encircled by them a subsiding basin system formed. The rate of subsidence varied spatially and temporally. It reached its maximum in the Middle Miocene, when true deep-sea environments prevailed. In the Upper Miocene subsidence went on at a reduced rate and shifted towards the deep basins.

The changes in the biota of the inland sea and the characteristic endemic animal life, recurring in the various stages, clearly indicate the paleogeographical links and alterations in the sedimentation environments.

There are three tectonic stages in the evolution of the basin system: in the Eggenburgian there still was easy communication with the world ocean. In the Ottnangian the contacts were broken up and characteristic endemic faunas developed. At that time, the Pannonian Basin was only linked with the western and eastern basins of the Parathetys.

In the Middle Miocene the rate of subsidence increased and broad sea arms opened towards the Tethys. This was the period when – within the Neogene – the richest biota populated the shallow and deep sea environments of sedimentation in the basin.

The Upper Miocene was a period of basin infilling. In the Sarmatian the area was completely isolated from the world ocean and formed an inland sea. In the Pannonian the inland sea was dissected into a lacustrine system with typical brackish, deltaic and fluviolacustrine seimentation environments.

On the Sarmatian/Pannonian boundary the basin was also separated from the Parathetys. An unambiguous paleogeographical link could be found with the eastern Parathetys in the Pannonian. The Pannonian evolution of the basin is a history of desalinisation and infilling. On the Miocene/Pliocene boundary over most of the basin area was a fluvial plain and lacustrine and deltaic sedimentation was only limited to the deep depressions.

KEY WORDS: Pannonian Basin, Infilling process, Paleogeography, Late Miocene, Central Paratethys.

RIASSUNTO: KORPÁS-HÓDI M. & BOHM-HAVAS M., *Evoluzione dell'ambiente sedimentario del Miocene e relazione paleogeografica del Bacino Pannonico (Carpazi).* (IT ISSN 0391-9838, 1998).

Lo sviluppo del Bacino Pannonico (Carpazi) nel Miocene è legato alla collisione delle placche Europea e Africana. Le Alpi e i Carpazi si sollevarono nel Miocene e, a causa dell'insorgere delle forze estensionali, all'interno di esse si formò un bacino subsidente. Il tasso di sollevamento fu variabile nel tempo e nello spazio, raggiunse il massimo nel Miocene Medio, quando prevalsero vari ambienti di mare profondo. Nel Miocene Superiore ci fu un rallentamento e una migrazione verso le profondità bacinali. I cambiamenti biotici e la vita degli esseri endemici, presenti in vario modo, stanno a indicare le conseguenti mutazioni paleogeografiche e le alterazioni degli ambienti sedimentari.

Vi furono tre fasi tettoniche nell'evoluzione del bacino:
- Nell'Eggenburgiano vi erano ancora comode comunicazioni con il mondo oceanico. Nell'Ottnangiano si interruppero le comunicazioni e si svilupparono caratteristiche faune endemiche. In quell'epoca il Bacino Pannonico era congiunto soltanto con i bacini occidentale e orientale della Paratetide.
- Nel Miocene Medio si fa un incremento della subsidenza e alcuni ampi bracci marini si aprirono verso la Tetide. Questo fu il periodo, nel Neogene, in cui i più ricchi popolamenti si ebbero negli ambienti di mare basso e profondo.
- Nel Miocene Superiore vi fu un periodo di riempimento. Nel Sarmaziano l'area fu completamente isolata dall'oceano e formò un mare interno. Nel periodo Pannonico la terra interna emerse e si formarono sistemi con ambiente di sedimentazione salmastro, deltizio e fluvio-lacustre. Al limite Sarmaziano-Pannonico il bacino fu separato dalla Paratetide. Un ambiguo allacciamento paleogeografico potrebbe essere individuato con la Paratetide orientale nel Pannonico. L'evoluzione del bacino nel Pannonico è una storia di desalinizzazione e di riempimento. Al limite Mio-Pliocene il bacino fu soprattutto una piana fluviale e lacustre e la sedimentazione deltizia si è confinata alle depressioni maggiori.

TERMINI CHIAVE: Bacino Pannonico, Processo di riempimento, Paleogeografico, Miocene Superiore, Paratetide Centrale.

INTRODUCTION

During the Miocene the Pannonian (Carpathian) Basin was a central part of the Paratethys inland sea, which stretched from the northern foreland of the Alps to Lake Aral in west to east direction. The Pannonian Basin developed in the Middle Miocene as a result of geodynamic events occurring in the Alpine-Mediterranean region. Re-

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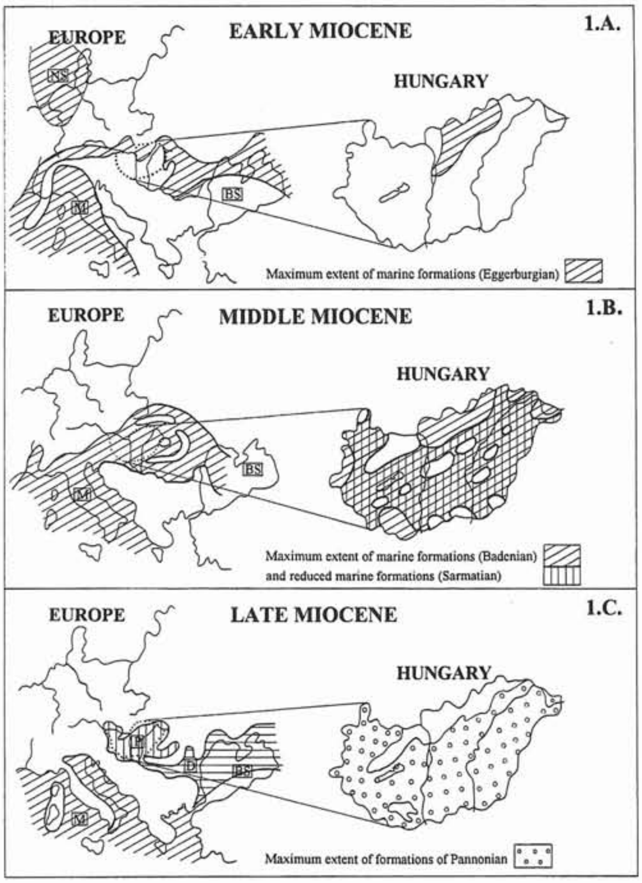

FIG. 1 - Paleogeographic sketch of Paratethys and Hungary for Miocene time. M - Mediterranean Sea; NS - North Sea; BS - Black Sea; P - Pannonian Basin; D - Dacian Basin (after Baldi 1986, Bérczi & *alii*, 1988, Steininger & *alii*, 1988).

garding its tectonic development, the basin was a «back arc type extensional basin that opened behind the coeval Carpathian thrust belt» (Royden, 1988). The separation of subbasins resulted from heterogeneous and diachronous tectonics.

The events of Miocene history of the Pannonian Basin were closely related to the geodinamic processes taking place in the area of the Paratethys. The latter controlled paleogeographic connections, changes in sedimentary environments (fig. 1), and evolution of the biota.

MIOCENE EVOLUTION

In early Miocene, the Paratethys was largely separated from the Mediterranean Tethys, and they were only connected through straits, while the connection with the North Sea fully ceased to exist (fig. 1A). The marine sedimentary basins became narrower. The terrestrial area of the Alps increased and intensively uplifted. Terrestrial fluvial sedimentation became also predominant within the Carpathian Basin. The sediments of onshore and basin facies stretch from the southern foreland of the Buda hills towards the NE as far as Sajóvölgy Basin.

At the end of the early Miocene, the contacts with Mediterranean area were broken, the Paratethys was completely isolated, and characteristic endemic faunas developed. At that time, the Central Paratethys was only linked with the western and eastern basins of the Paratethys.

As the Middle Miocene paleogeographic map (fig. 1B) on the Paratethys and the distribution of Middle Miocene deposits in Hungary shows, the link with the foreland of the Northern Alps through the Rhone Basin was lost direct communication developed towards the Mediterranean. The Badenian (particularly, the Early Badenian) was the period of a major transgression with of the Pannonian Basin inundated. Sedimentary basins were controlled and created by volcanic and tectonic events (Harangi & *alii*, 1995). Within the Neogene, the richest biota, first of Mediterranean nature, then showing the influence of the Eastern Paratethys, populated the shallow and deep sea environments of the basins.

At the end of the Middle Miocene, the Paratethys became an inland sea with a reduced salinity. At that time the Pannonian Basin was only linked with the eastern Paratethys. The major part of the basin was covered by water, and a shallow-water sedimentation and the dominance of reduced marine fauna were typical.

The paleogeographic map (fig. 1C) shows late Miocene situation with the greatest distribution of Pannoniam formations. The connection of the Pannonian Basin with the eastern Paratethys was broken at around the Sarmatian/Pannonian boundary and a brackish lake with an endemic fauna was formed. The renewal of the paleogeographic connection of the basin in the Pannonian is still disputed today. In our opinion, the connection with the eastern Paratethys is likely to have renewed from time to time through a narrow channel. Also, it does not exclude that it might have been connected with the Mediterranean region through the Vardar zone.

PANNONIAN EVOLUTION

In the Pannonian the basin became limnic and was filled. The major feature of the infilling process was that the brackish lacustrine sedimentation withdrew towards the central depression of the basin due to delta progradation (Bérczi & Phillips, 1985). At the Mio/Pliocene boundary, the brackish lacustrine/delta sedimentation ended and was replaced by a fluvio-lacustrine sedimentation (Jámbor Á. & *alii*, 1987) over most of the area. Basin infilling was controlled by tectonic, climatic and probably global eustatic events.

The infilling of the basin

The uplifting Carpathians changed the regime of sediment transport and increased the rate of sedimentation. Deposits of several thousand metres thickness accumulated in the basin (fig. 2), increasing from the margins towards the centre (Jámbor, 1989). Sedimentation was controlled by diachronic tectonics and the thermal subsidence

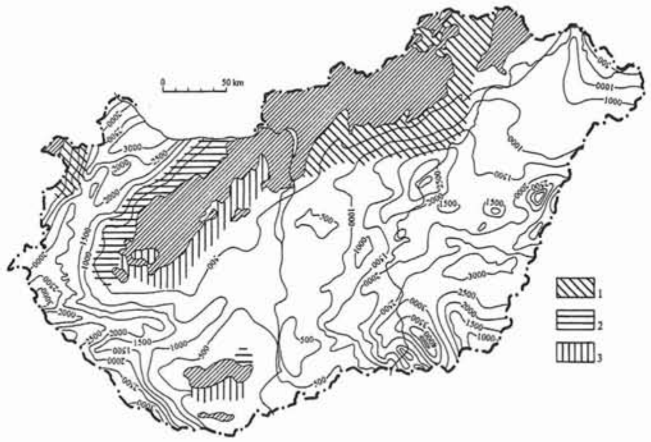

FIG. 2 - Thickness of Pannonian s.l. deposits and characteristic marginal environments of the Pannonian Basin during the Early Pannonian. 1 - delta & flood plain; 2 - brackish lacustrine; 3 - lagoon.

of the basin. The rate and time of thermal subsidence increased with the distance reckoned from the Carpathian thrust belt (Horváth & *alii*, 1988; Royden, 1988). The infilling of the basin went on from the arc of the Carpathians towards the deep central depressions.

As shown in a map compiled on the basis of a seismic sequence research of the Great Hungarian plain (Vakarcs & *alii*, 1994), the shelf edge went on towards the southern depression centre and the filling was almost symmetric. Its position could also be probably determined in Transdanubia (fig. 3) from paleontological and sedimentological investigations. In Pannonian times, the mountain areas today in Transdanubia were already obstacles to the transport of materials from the Carpathians and, to a small degree, erosional surfaces developed.

The Pannonian sediments in the area of Hungary consist of two units. The lower is characterised by pelitic sediments deposited from suspension in brackish, open-water, lacustrine/deep-water delta paleonvironment with turbidite intercalations in the deep subbasins and troughs and with shallow-water lacustrine/delta/alluvial sedimentation in the foreland of mountains (Peremarton Group - fig. 2). Previously, this sequence was classified as early Pannonian. In the upper part of the profile the deposit became coarser. The considerably increased sand fraction indicates shallower water (delta progradation). Sedimentation took place in a shallow lacustrine/delta front/delta plain fluviolacustrine paleoenvironment (Dunántúl Formation Group) (Jámbor & *alii*, 1987; Pogácsás & Révész, 1987; Juhász, 1994).

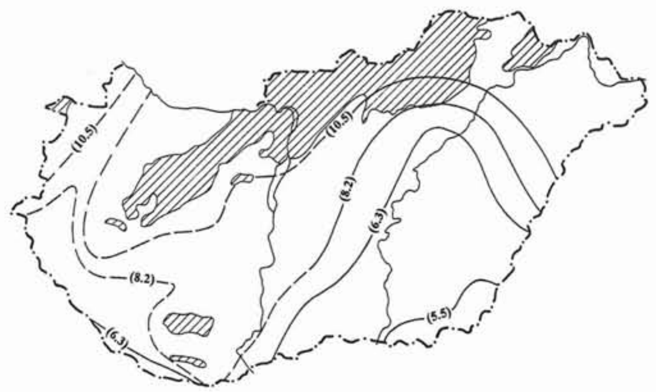

FIG. 3 - Sedimentation of the Pannonian Basin in the territory of Hungary. Hatching - present mountain areas. Position of shelf edge in discrete time points given in brackets in Ma BP: solid line - proved by seismic sequence stratigraphy (after Vakarcs & *alii*, 1994), dashed line - by sedimentology and malacology.

Influence of climate and global eustatic events

Infilling was accompanied by a relative decrease in water level. The paleocenological examination of borehole profiles, however, also indicates rises in water level (fig. 4). Local tectonic events and thermal subsidences played a very important part in it. In regional relative rises in water level were also controlled by climatic and/or global eustatic events. Authors' investigations show that the influence of global eustatic events are more significant than local cli-

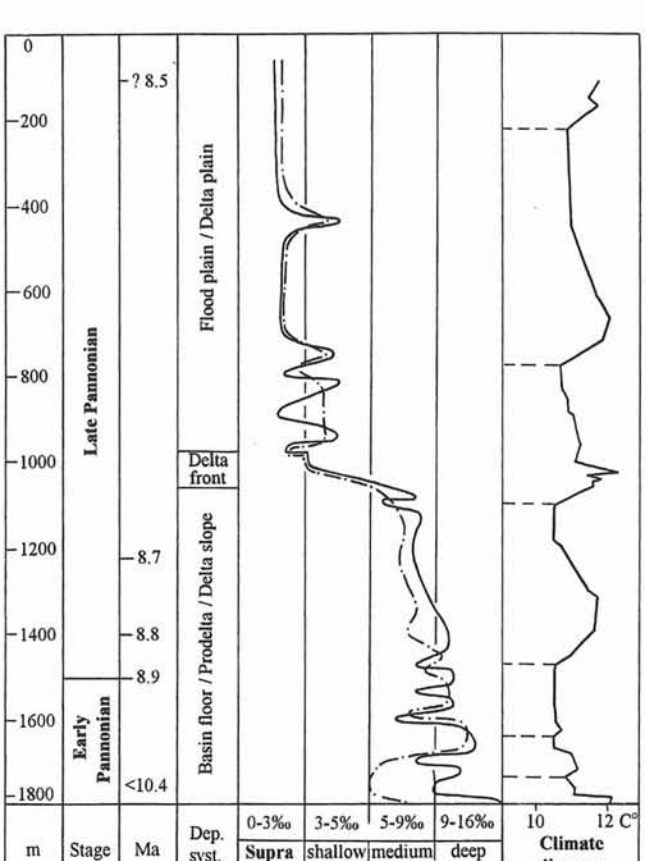

FIG. 4 - Correlation of changes of salinity (solid line) and water depth (dashed line) with climate cycles in borehole Szombathely-II. Salinity (Ostracoda, A. Szuromi-Korecz), water depth (Mollusca by M. Korpás-Hódi), climate diagram (pollen by E. Nagy-Bodor). The diagrams are shown in correlation with paleomagnetic time (Lantos & *alii*, 1992), sedimentation system (Philips & *alii*, 1989).

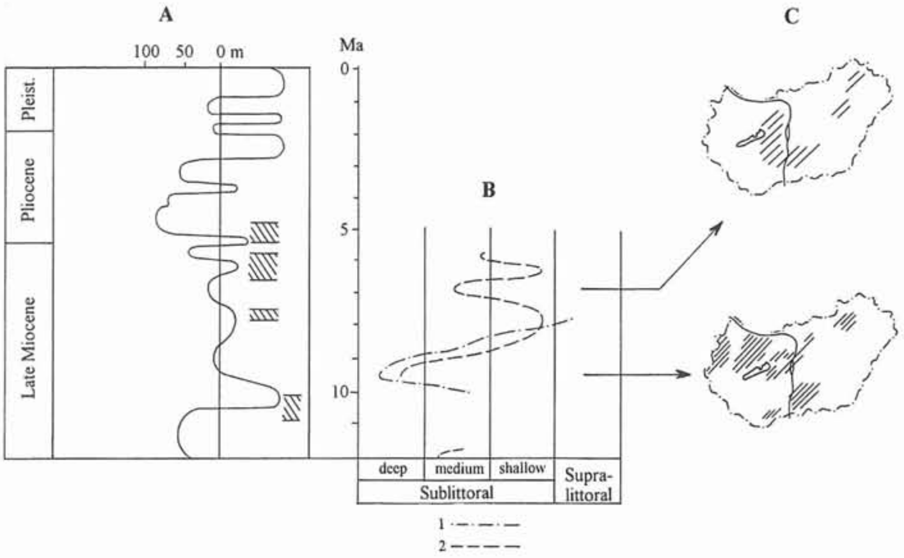

FIG. 5 - Change of relative water-depth in the Pannonian Lake correlated with eustatic fluctuaions of sea level. A - Eustatic fluctuations of sea level. Hatched intervals indicate relative water-level decrease/hyatus at the northern edge of the Great Hungarian Plain (Pogácsás, & *alii*, 1990). B - Change of relative water-depth in boreholes Szombathely-II (1) and Kaskantyú-2 (2), based on molluscinvestigation. The curves represent general water-level decrease in the Late Miocene Pannonian Lake. The trend of water-depth decrease caused by basin sedimentation is broken by stages of water-level increase (~9.2, ~7.0, ~5.9 Ma) and water-level decrease (~12.0-10.4, ~8.0, ~6.6 Ma) correlated with eustatic events. C - Areas where the relative lake level changes could be correlated with eustatic sea level fluctuations.

mate change. Juhász & *alii* (1995) interpreted the cyclic variation of bed thickness as an influence of climate cycles and found a cyclicity ~400, ~60 Ky in the deposits of the delta-plain. The local climate curves plotted on the basis of a pollen spectrum exhibit a cyclicity of ~400 Ky (Korpás-Hódi & *alii*, in press).

The relationships between changes in water depth, salinity and climate cycles is not yet clear (fig. 4). In authors' interpretation, the impact of great climatic cycles of ~400 Ky on cyclic environmental changes can be masked by local tectonics and global eustatic influences. Pogácsás was the first to link, from seismic facies and stratigraphic studies, water level changes with global eustatic sea level changes in the Pannonian Basin (Pogácsás & *alii*, 1990). The same result was obtained by authors through the analysis of relative changes in water depth and salinity from a paleoecological analysis of molluscan fauna and of the primary sequence examination of the Little Hungarian Plain (Hódi-Korpás & *alii*, 1993 - fig. 5). Eustatic change as a simultaneous regional event was superimposed on water level changes of diachronous tectonic origin.

Paleogeographic connections

Global eustatic change is only effective through a direct contact with sea. Did the Pannonian Basin have such a contact? This is still a disputed issue (Müller & Magyar, 1992; Korpás-Hódi, & *alii*, in press). Neither the connection nor the complete landlocking (isolation) are clearly proved.

The Pleistocene events concernig the Black Sea justify that the complete isolation created an enormous limnic mass of water over some 10 thousand years (Sorokin, 1983). In a geochemical analysis of early Pannonian fossil groundwater in Hungary, a salinity less than that of sea wa-

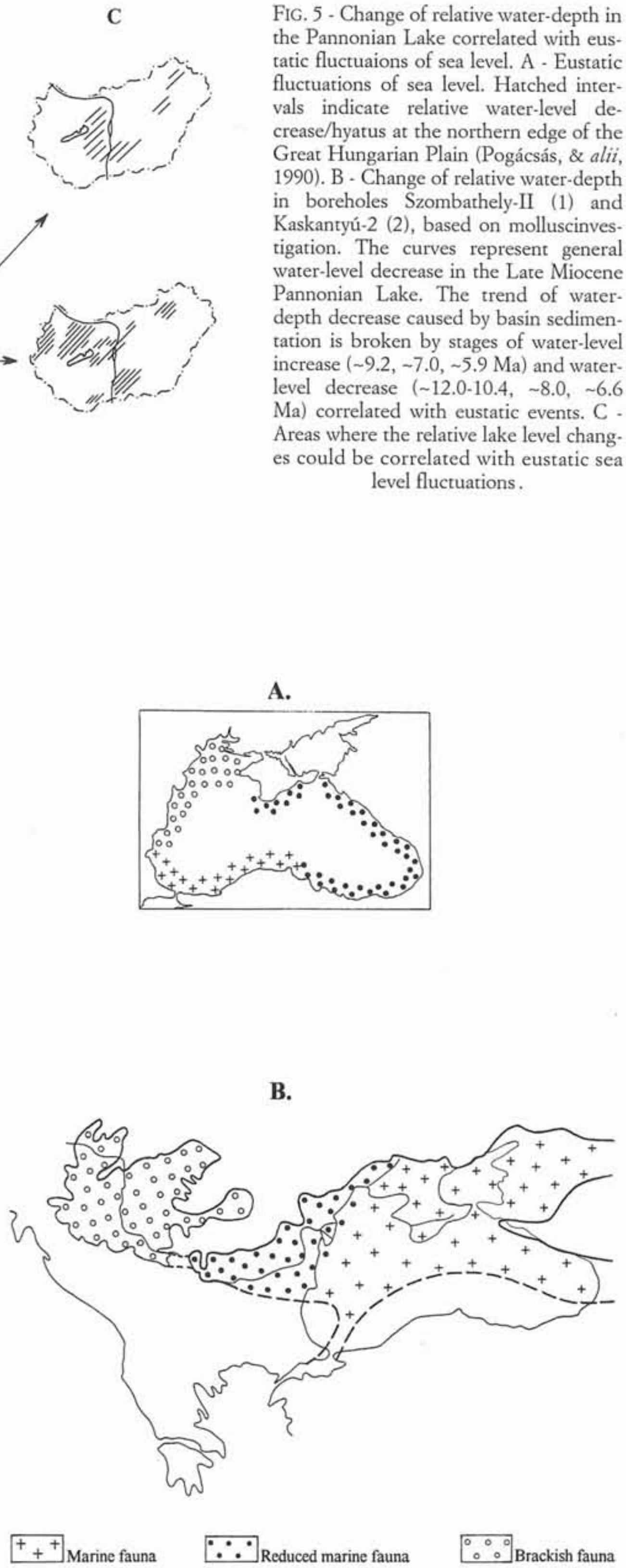

FIG. 6 - Comparison of paleozoogeographical regions of Paratethys and zoogeographical regions of Black sea. A - Zoogeographical regions of Black Sea (Yokubova in Zenkevich, 1963); B - Paleozoogeographical regions of Paratethys (after Hámor & *alii*, 1988; Steininger & Rögl, 1985).

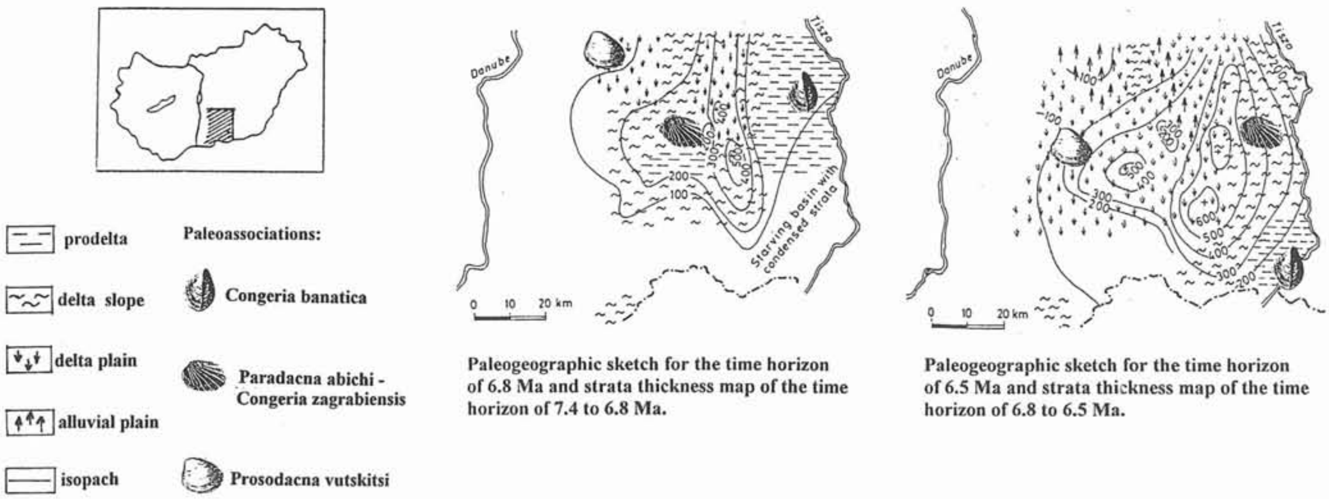

FIG. 7 - Correlation of benthic paleoassociations and depositional systems (after Korpás-Hódi & *alii*, 1992).

ter but a similar ion composition were detected (Kleb, 1971). As generally known, the decrease in water level regionally occurring at the lowermost Pannonian was followed by a transgression, an enormous increase in water mass. If the basin had been perfectly isolated, then, as in the Black Sea, this mass of water must have turned limnic by climatic influence. Consequently, a link with the sea is also probable on the basis of salinity. In the Pannonian global eustatic change, through the intermittently opening sea link, may have effectively influenced sedimentation.

Relying on a zoogeographical analogy with the Black Sea, a paleozoographic model of the Paratethys has been outlined, providing an optional interpretation of the paleogeographic connection of the Pannonian Basin (fig. 6). The possible paleogeographic link is not restricted to the eastern Paratethys only. A direct Mediterranean link through the Vardar valley cannot be excluded either.

Sedimentation systems and biota

A very close connection can be detected between sedimentation system and the biota. Within the range of each species, their occurences are controlled by paleonvironmental factores. Different paleoassociations were formed

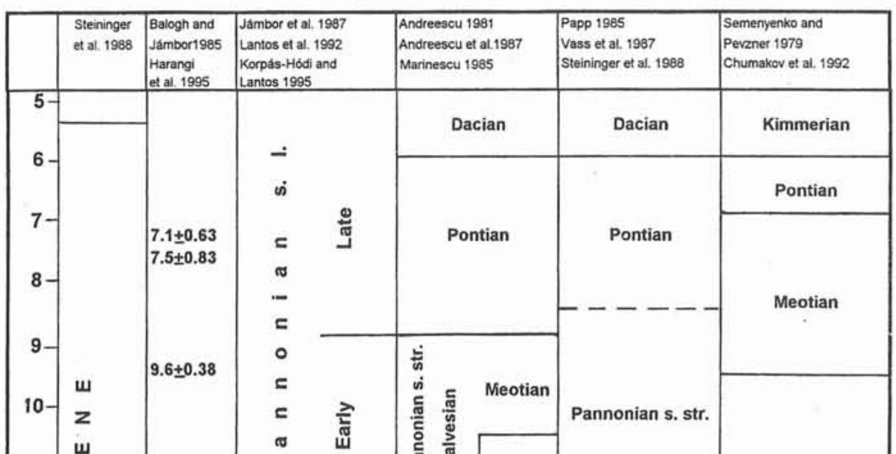

FIG. 8 - Chronostratigraphical stages of Paratethys and their correlation.

due to the different environmental factores of the various sedimentary systems. Even within one subbasin the organization of brackish biota was more dependent on the environment than on age (Korpás-Hódi, 1983; Korpás & *alii*, in press).

The benthic fauna prograded along the delta. The biota of sedimentation systems of different age but of the same type in the subbasins are very similar (fig. 7, Pogácsás & *alii*, 1990; Juhász & Magyar, 1992; Korpás-Hódi & *alii*, 1992).

Migrations

Judging the migration of the biota always corresponds to the level of correlation knowledge of the specific age. Today it is held that the typical direction of migration was W to E in the Paratethys (Taktakishvili, 1977). In accordance with the infilling of the basins, the species could find a better habitat towards the east whereas from west they were blocked by an ecological barrier.

The chronostratigraphic chart (fig. 8) of the Paratethys region shows that identical stage names cover different time spans but it is also visible that the same stage names fill younger time span in the eastern Paratethys than in the area of the Central Paratethys. The identical stage names express a similarlity of molluscs, and show a faunal migration from W to E.

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