



NEOGENE OF THE PARATETHYAN REGION

6TH WORKSHOP ON THE NEOGENE OF CENTRAL AND SOUTH-EASTERN EUROPE

AN RCMNS INTERIM COLLOQUIUM

PROGRAMME

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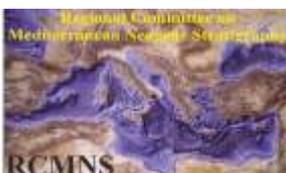
ABSTRACTS

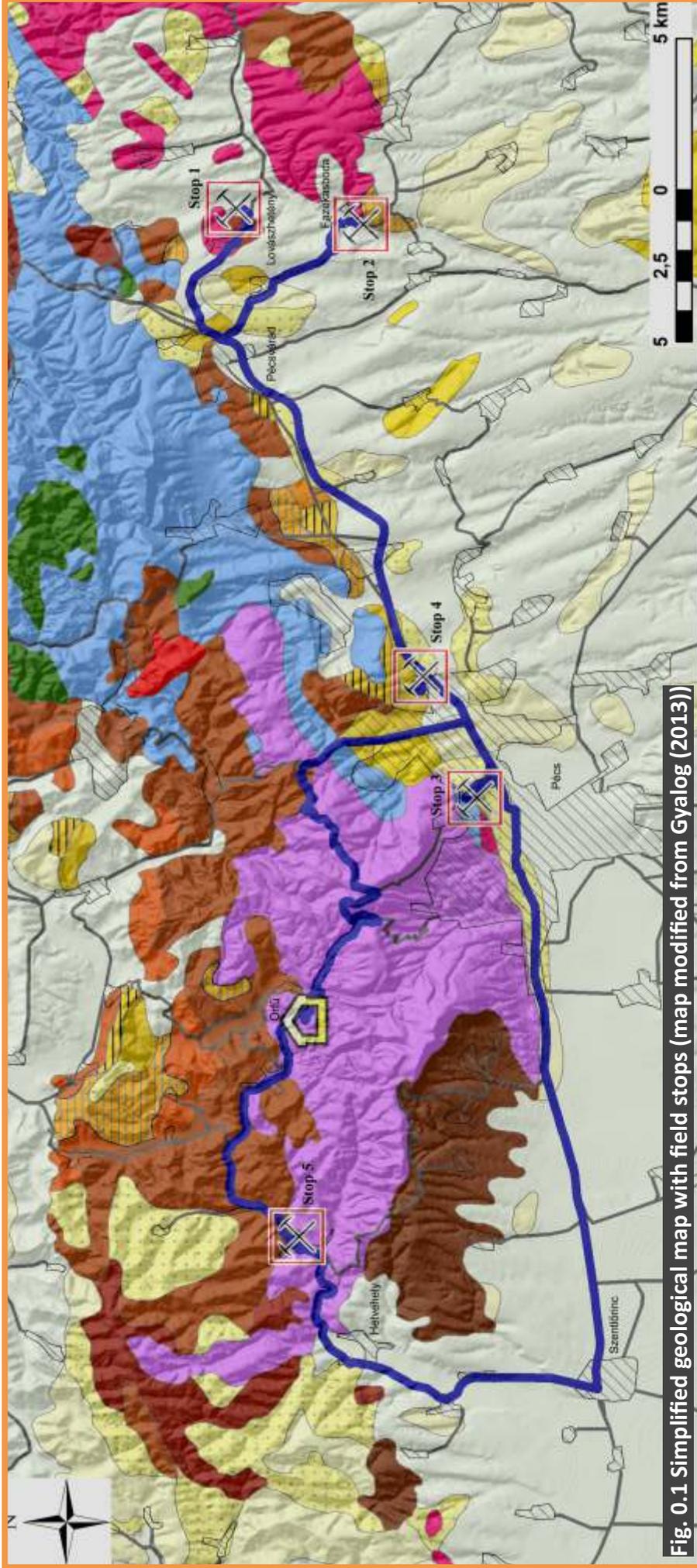
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FIELD TRIP GUIDEBOOK

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31 MAY - 3 JUNE 2015, ORFŰ, HUNGARY





Legend

- Quaternary terrestrial sediments
- Pannonian lacustrine delta series (Újfalu Fm.)
- Pannonian lacustrine shoreface sand & gravel (Kálfa Gravel Fm.)
- Pannonian lacustrine offshore calcareous marls (Endrőd Fm.)
- Sarmatian nearshore limestones and marls (Tinnye & Kozárd Fms.)
- Upper Badenian offshore sediments (Szilágy Claymarl Fm.)
- Upper Badenian coal-bearing sequence (Hidas Coal Fm.)
- Middle-Upper Badenian Leitha Limestones (Pécsszabolcs and Rákos Mbs.)
- Middle Badenian offshore to deep marine sediments (Tekeres Schlier Fm.)
- Karpatian - Badenian shallow-water brackish to marine clastics (Budafa Fm.)
- Eggenburgian - Otnangian andesite (Mecsek Andesite Fm.)
- Eggenburgian to Karpatian fluvial sequence (Szászvár Fm.)
- Cretaceous carbonates and volcanics
- Jurassic clastics and carbonates
- Triassic clastics and carbonates
- Permian clastics and rhyolite
- Paleozoic crystalline basement

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Programme
Abstracts
Field Trip Guidebook

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PROGRAMME, ABSTRACTS AND FIELD TRIP GUIDEBOOK

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Cover photo: Uppermost part of the Pannonian calcareous marls and their transition to the overlying –still Pannonian–coarse sands at Pécs-Danitzpuszta. Younging is towards the right.

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Dear participants,

welcome to the 6th International Workshop on the Neogene of Central and Southeastern Europe. The initiation of this biennial international workshop 10 years ago was an excellent idea; after Serbia (2005), Austria (2007), Romania (2009), Slovakia (2011) and Bulgaria (2013), this year Hungary hosts this popular meeting.

For a long time, research of the Paratethyan Neogene lagged behind that of the Mediterranean. In the past decade we have seen a spectacular development in understanding the Neogene evolution of the Paratethyan area. The growing amount of high-precision geochronological data (radiometric and magnetostratigraphic ages), new models of the Badenian Salinity Crisis, the vast AAPG Memoir volume on the Carpathians and their foreland, the extensive ESF-EUROCORES TOPO-EUROPE SourceSink programme, compilation of the monumental FreshGen database, and the increasing involvement of industrial seismic and borehole data into academic research are but a few characteristic landmarks of this development.

Scientific breakthroughs are usually preceded by patient observations and meticulous analyses – and, of course, hot and passionate scientific debates. This workshop provides an ideal forum to share our observations, ideas, hypotheses, and to discuss them in a critical but familiar environment.

For the venue of this conference we selected a location which is fully able to ensure the informal and distraction-free physical environment to our workshop. Following the tradition of NCSEE workshops, however, we would like to offer you a taste of the local culture, therefore the conference program includes a brief visit to the medieval city of Pécs, including a UNESCO World Heritage site – the early Christian cemetery in the city centre.

I hope you'll enjoy your stay.

On behalf of the organizing committee,

Imre Magyar

PROGRAMME

1 June 2015

08:30-08:45 Opening of the workshop (dr. Tamás Hámor, vice president of the Hungarian Geological Society)

08:45-10:45 Invited presentations, Chairman: MAGYAR I.

08:45-09:15 HORVÁTH F. - *Macrostratigraphy and geodynamics of the Pannonian basin*

09:15-09:45 NAGYMAROSY A. - *Styles of deposition in the Neogene basins of Hungary*

09:45-10:15 HARANGI SZ. - *The Neogene to Quaternary volcanism in the Carpathian-Pannonian region: does the plate tectonic concept work here?*

10:15-10:45 SEBE K. - *Neogene stratigraphy in the Mecsek region*

10:45-11:15 Coffee break

11:15-12:45 Early and Middle Miocene geochronology, Chairman: HARANGI SZ.

11:15-11:30 DE LEEUW A. *et al.* - *Paleomagnetic and geochronologic constraints on the Miocene evolution of semi-isolated basins in southeastern Europe*

11:30-11:45 SANT K. *et al.* - *A different stratigraphic approach to reconstruct the Karpatian and Badenian seas in Central Europe*

11:45-12:00 PALCU D. *et al.* - *The age of the Badenian/Sarmatian Extinction Event - New insights on the chronology and the paleogeography of the Middle Miocene Paratethys Realm*

12:00-12:15 LESS Gy. *et al.* - *Dating of central Paratethyan deposits with SIS (Sr-isotope stratigraphy)*

12:15-12:30 LUKÁCS R. *et al.* - *Combined (U-Th)/He and U-Pb zircon dating to constrain the eruption events of the early to middle Miocene ignimbrite flare-up in the Pannonian basin, eastern-central Europe*

12:30-12:45 BUKOWSKI K. *et al.* - *Miocene tuffite levels from new boreholes Busko Pig-1 and Kazimierza Wielka Pig-1, Carpathian foredeep (Poland)*

12:45-14:00 Lunch break

14:00-15:15 Badenian and Sarmatian I., Chairman: SZTANÓ O.

14:00-14:15 BÁLDI K. - *New advancements in Badenian research (16.3-12.8 Ma)*

14:15-14:30 TÓTH E. *et al.* - *The Sarmatian Stage in Hungary*

14:30-14:45 SZURÓMI-KÖRECS A., SELMECZI I. - *Middle Miocene evaporites from borehole successions in Hungary*

14:45-15:00 BÁLDI K. *et al.* - *New discovery of mid-Miocene (Badenian) evaporites inside the Carpathian arc - possible implications for global climate change and Paratethys salinity*

15:00-15:15 DÁVID Á., FODOR R. - *Paleoichnology of a Badenian rocky shore*

15:15-15:45 Coffee break

15:45-16:45 Badenian and Sarmatian II., Chairman: KOVÁČ M.

15:45-16:00 WYSOCKA A. *et al.* - *A comprehensive review of the Middle Miocene in the marginal part of the Carpathian Foredeep basin (Poland and Ukraine)*

16:00-16:15 HOLCOVÁ K. *et al.* - *Revision of holostratotypus and faciostratotypes of the Moravian from the Czech and Slovak Republic (Oslavany, Zidlochovice, Chlaba, Salka): multiproxy study*

16:15-16:30 HUDÁČKOVÁ N. *et al.* - *Stratigraphical potential of Foraminifera and calcareous nannoplankton in the Upper Badenian and Sarmatian sediments of Central Paratethys*

16:30-16:45 RUNDIĆ Lj. *et al.* - *The Middle Miocene transgression: new data from the vicinity of Bor, eastern Serbia*

17:00 Departure to Pécs, visit to the UNESCO World Heritage site

2 June 2015

08:00 **Field Trip: Neogene stratigraphy in the Mecsek region**

3 June 2015

08:00-09:30 **Sedimentology and stratigraphy of Lake Pannon deposits**, Chairman: HARZHAUSER M.

08:00-08:30 SZTANÓ O. - *Rivers, deltas, turbidite systems: an overview of sedimentation in Lake Pannon*

08:30-08:45 VISNOVITZ F. *et al.* - *Progradation of Late Miocene delta clinoforms in the southern foreland of the Transdanubian Central Range*

08:45-09:00 TÓKÉS L. *et al.* - *Confined turbidite basins in the Lake Pannon - Examples from southwestern Hungary*

09:00-09:15 ŠUJAN M. *et al.* - *New constraints in the Upper Miocene and Pliocene stratigraphy of the Danube Basin based on application of the authigenic $^{10}\text{Be}/^9\text{Be}$ dating method*

09:15-09:30 JOHNSON M.R., GEARY D.H. - *Stable isotope ecology of Hipparion from the Late Miocene Pannonian basin*

09:30-10:45 **Poster session**

10:45-11:15 Coffee break

11:15-12:45 **Regional basin evolution studies**, Chairman: RUNDIĆ Lj.

11:15-11:30 ŁOZIŃSKI M. *et al.* - *The Orava-Nowy Targ Basin: tectonic activity at basin margins vs. sedimentary record*

11:30-11:45 KOVÁČ M. *et al.* - *Cenozoic sedimentary record at the Central Western Carpathian and Northern Pannonian domains junction: interpretation of a complex geodynamic evolution*

11:45-12:00 RYBÁR S. *et al.* - *Sediment provenance and the influence of paleoenvironmental change on deposition in the northern Danube Basin. Blatné depression case study.*

12:00-12:15 OROSS R. *et al.* - *Structural development of the Drava basin and the related hydrocarbon fields in the Barcs region*

12:15-12:30 HAJEK-TADESSE V. *et al.* - *Early Miocene deposits in North Croatia (Slavonia) - Review of the work and results*

12:30-12:45 YANEVA M. *et al.* - *Sedimentary model of Lom coal basin, NW Bulgaria*

12:45-14:00 Lunch break

14:00-15:45 **Paratethyan faunas and biodiversity**, Chairman: DULAI A.

14:00-14:15 POPOV S.V. *et al.* - *Eastern Paratethys Miocene deposits, mollusks and nannoplankton of the northern Iran*

14:15-14:30 RADIONOVA E. P. *et al.* - *Diatoms in the Sarmatian, Maeotian and Lower Pontian (the Taman Peninsula)*

14:30-14:45 STUDENCKA B. *et al.* - *Bivalve fauna from the Silesian nappe, Polish Carpathians: evidence for the early history of the Paratethys*

14:45-15:00 HARZHAUSER M. *et al.* - *A world of lakes - European Neogene freshwater systems*

15:00-15:15 NEUBAUER T. A. *et al.* - *Developments of freshwater biodiversity during the late Cenozoic: impact of geodynamics and climate on hotspot formation*

15:15-15:30 HYŽNÝ M. - *Miocene Paratethyan decapod crustaceans: diversity and distribution patterns*

15:30-15:45 HÍR J. - *Microvertebrates from the type section of the Kozárd Formation (Miocene, Sarmatian; N. Hungary, Nógrád county)*

15:45-16:00 **Closing of the conference and invitation to the 7th International Workshop on NCSEE**

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TECTONIC AND STRATIGRAPHIC EVOLUTION OF ASYMMETRIC EXTENSIONAL BACK-ARC BASINS: SEISMIC INTERPRETATION STUDY FROM THE PANNONIAN BASIN

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²Netherlands Research Centre for Integrated Solid Earth Science, Utrecht University, Faculty of Geosciences, The Netherlands

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The evolution of the Pannonian Basin is generally thought to be driven by subduction roll-back associated with mantle flow dynamics. The Miocene back-arc extension resulted in the formation of dominantly half-grabens in the hanging wall of low-angle detachments and listric normal faults, associated with coeval large-scale exhumation of their footwalls. To quantify the evolution of these asymmetric extensional structures, a novel kinematic and seismic sequence stratigraphic interpretation was performed. Based on reflection terminations and characteristic seismic facies we separated systems tracts of the half-graben deposits that formed as a result of interplay between subsidence, sedimentation and water-level variations. Lower order systems tracts were defined by separating rift initiation, rift climax, immediate post-rift and late post-rift systems tracts (after Prosser 1993), while a higher order transgressive-regressive cyclicity and associated unconformities were locally identified in the syn-tectonic basin fill (Fig. 1).

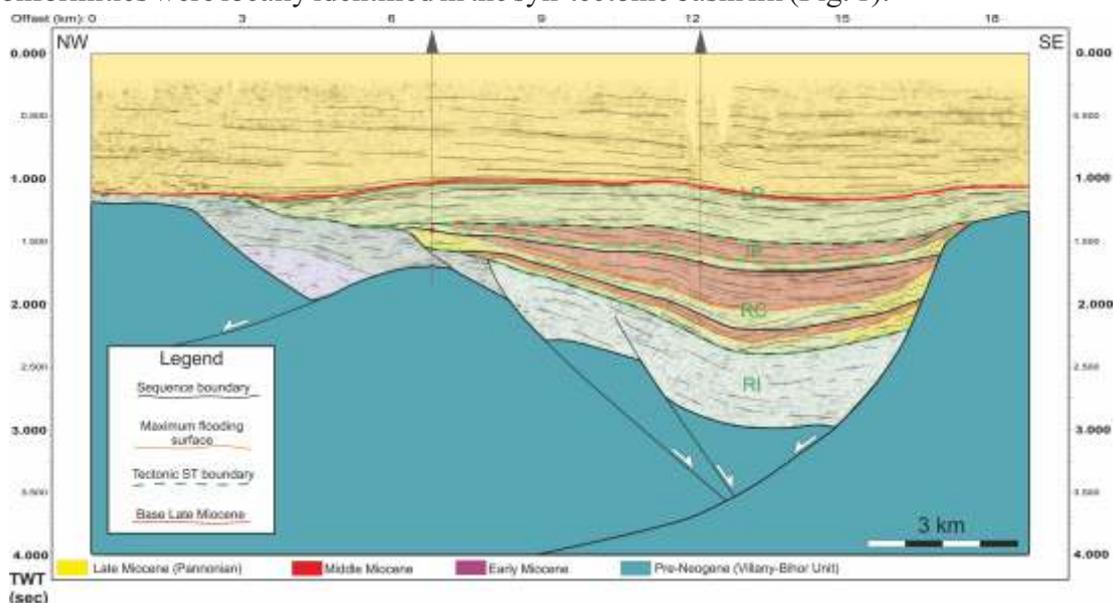


Fig. 1.: Interpreted reflection seismic profile from the Kiskunhalas Trough. Karpatian rift climax and Badenian immediate post-rift systems tracts are subdivided into three transgressive-regressive cycles.

Connecting these observations demonstrates that extension migrated in time and space across the basin. Extension started during Early Miocene in the oldest sub-basins, while Middle Miocene rift climax is quite common in the entire study area (e.g. Matenco and Radivojevic 2012). The youngest syn-tectonic strata were deposited during Late Miocene times in the eastern parts of the Pannonian Basin, for instance, in the Derecske, Makó and Szeged Troughs. The syn-rift/post-rift boundary cannot be interpreted as a discrete event in the entire basin system, because it is a progressive, process-related expression. The obtained results significantly improve the classic ideas of syn-rift/post-rift evolution of the Pannonian Basin.

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3D ANALYSIS OF COMPACTION RELATED TECTONIC AND STRATIGRAPHIC FEATURES OF THE LATE MIOCENE SUCCESSION FROM THE PANNONIAN BASIN

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The Pannonian Basin of Central Europe is a classical back-arc basin, surrounded by the Alpine, Carpathian and Dinaric mountain belts. Asymmetric extension created several separate half-grabens in the area during the Neogene. In the Early to Middle Miocene the basin evolved as part of the Central Paratethys. From the beginning of the Late Miocene the uplift of the Carpathians separated the Pannonian Basin from the sea, thus creating Lake Pannon. The lake persisted for ca. 7-8 mys and it was progressively filled up by clastic materials transported into the lake by rivers, like the paleo-Danube and paleo-Tisza from the North and minor sediment input derived from the southern hinterland (Magyar et al. 2013, Ter Borgh et al. 2014).

We performed 2D and 3D seismic interpretation in the few-km-thick Late Miocene basin fill in order to understand the evolution of the basin. The paleo-water depth of the lake was estimated based on the height of the prograding shelf-margin slope clinoforms from different parts of the basin. During our paleobathymetric calculations we performed precise depth conversion of the seismic data and decompaction of the slope clinoforms (Algyő Formation) on tectonically restored sections (Fig. 1.). Our calculations showed that water depth of Lake Pannon could have reached more than 1000 metres in the deepest basins during early Late Miocene (early Pannonian s.l.) times. Recent height of these clinoforms is only ca. 5-600 metres due to the burial and associated compaction effect of the slope sediments.

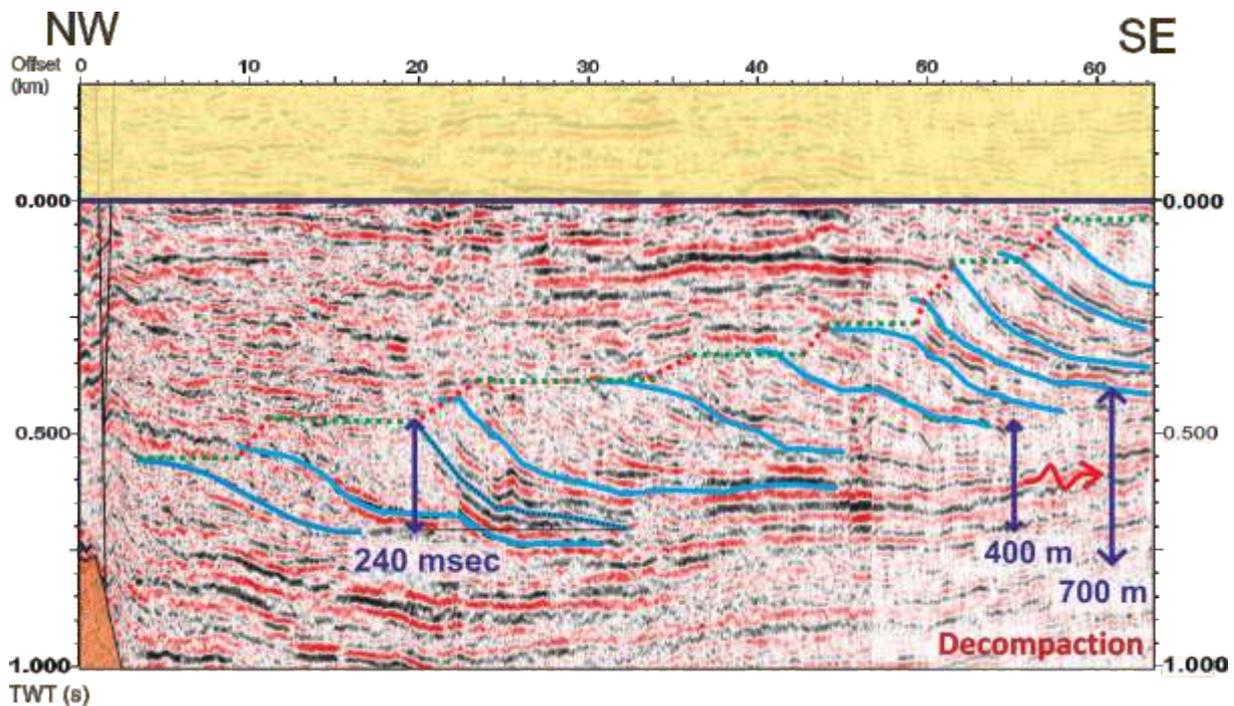


Fig. 1.: Flattened reflection seismic profile from the Makó Trough. The shelf-edge trajectory (see also Sztanó et al. 2013) and the shelf-margin slope clinoforms are indicated in the figure. An example of our paleobathymetric calculation is also shown.

Our seismic interpretation also demonstrates the importance of differential compaction induced normal faulting above basement highs (e.g. Grow et al. 1994). These features have been overlooked in the Pannonian Basin and have been potentially misinterpreted. We analysed the 4D development of such a fault system using 3D seismic data and precise decompaction of the sediments overlying the basement high. We propose a method to differentiate faults with tectonic origin and compaction-induced structures. Differential compaction also plays a major role in the evolution of sediment transport routes at different scales.

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NEW ADVANCEMENTS IN BADENIAN RESEARCH (16.3-12.8 MA)

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The aim of this presentation is twofold: first, to give a general overview of Badenian research, and second, to focus on the new developments following the last RCMNS NCSEE interim meeting in Varna in 2013. This was achieved by listing general facts about Badenian research and referring only to authors publishing their results from 2013 to the present day, exceptionally from 2012. The compilation presented here is an attempt to call attention to new developments in Badenian research, without aiming at the impossible: i.e., to list all noteworthy publications of this period.

According to Scopus, Elsevier's search program, over the last two years (2014 until today) 55 articles popped up for the search words "Badenian" and "Paratethys". By the time this abstract is read by you at the conference, there might perhaps be a dozen more. Thus we can say, the Badenian of the Paratethys is still a hot topic for the mere ~4 million years of geologic time it encompasses. Just for comparison: a similar literature search gave for Kiscellian, Eggenburgian, and Egerian altogether 12 articles, for Karpatian 17, while the succeeding Sarmatian and Pannonian were dealt with by a similar number of publications as the Badenian. This demonstrates the popularity of the younger, mostly Miocene Paratethyan stages as research topics.

The Badenian turns out to be a favorite topic, not just because of its longer period of time (~4 Ma) among shorter Paratethyan stages (e.g. Sarmatian ~1 Ma), but also because it was an eventful period between 16.3-12.8 Ma in Earth history (Hohenegger et al., 2014). Studying these events is keeping us researchers busy, intrigued as we are by the interactions of these local and global systems: the Paratethys and the World Ocean. During the Mid-Miocene Climate Optimum (MCO) at the beginning of the Badenian subtropical coral reefs lived in the Central Paratethys; and so the Leitha Limestones were formed (Holcová et al., 2014; Jost et al., 2015; Prista et al., 2015; Reuter et al., 2012; Utescher et al., 2015; Wiedl et al., 2013; Wiedl et al., 2014). Later a drastic global cooling took place, referred to as the Middle Miocene Climate Transition. This is visible on every deep water $\delta^{18}\text{O}$ curves in the deep oceans showing the appearance of cold deep water, indicating the onset of the oceanic regime reigning today. In the meanwhile, here in the Central Paratethys evaporites were formed during the short period of the Badenian Salinity Crisis (BSC) (Hohenegger et al., 2014; Peryt, 2013a; Peryt and Anczkiewicz, 2015), and the rich subtropical fauna became impoverished as a prelude to the non-marine stressful environments of succeeding Paratethys stages. The Leitha Limestones appearing at different time intervals show an ecologic succession where older members are rich, diverse reefs of optimal conditions to impoverished younger formations of reduced diversity.

Concerning stratigraphy the new boost in research is derived from three sources: absolute age determinations (de Leeuw et al., 2013; Hilgen et al., 2012; Mandic et al., 2012; Śliwiński et al., 2012; Szakács et al., 2012), astronomical tuning (Hohenegger et al., 2014; Hohenegger and Wagnreich, 2012), magnetic stratigraphy (Hohenegger et al., 2014; Selmeczi et al., 2012) and their combinations. The latest work on Badenian stratigraphy suggesting a new subdivision is based on astronomically tuned geomagnetic polarity reversals, paleoclimatic events, biozones and sea-level changes (Hohenegger et al., 2014). The actual new developments discussed here are concerning three boundaries regarding the Badenian: the Karpatian/Badenian boundary defining the beginning of the Badenian age, the Langhian/Serravalian boundary dividing the Badenian in two parts, and the Badenian/Sarmatian boundary. This latest boundary, can be defined by the appearance of Sarmatian fauna traditionally. The Karpatian/Badenian boundary is known not to coincide with the Bourdigalian/Langhian boundary, but differing by less than half a million years. Defining the base of the Badenian on LOZ of *Praeorbulina sicana* is still the best option in spite of the taxonomic problems; tying it to nannoplankton stratigraphy is problematic because of strong environmental influence on high or low occurrences of species defining e.g. acme zones.

The lower boundary of the Badenian shifted down from the bottom of the Lower Lagenid Zone to encompass more lithostratigraphic units; thus the benthic foraminifera Lower Lagenid Zone is no longer at the beginning of the Badenian (Hohenegger et al., 2014). The consequences of these changes concerning local stratigraphy is still to be tested by looking at particular sequences at other CP locations.

The timing and environment of the evaporite formation during the Badenian Salinity Crisis (BSC) has received much attention (Gebhardt and Roetzel, 2013; Gonera, 2013, 2014; Harzhauser et al., 2014; Hohenegger et al., 2014; Peryt, 2013a, b; Peryt and Anczkiewicz, 2015). There appears to be general consensus, that the BSC is an isochronous event in the Paratethys. The relative position of the Langhian/Serravalian boundary is defined by the cooling event Mi3b based on $\delta^{18}\text{O}$ curves at 13,82 Ma (Hilgen et al., 2012). This isotope shift based boundary on the local scale is dividing the Badenian into two parts, the Early and Mid- Badenian (Moravian) versus the Late Badenian (Wieliczian, Kosovian) (Hohenegger et al., 2014). There are new contributions concerning connections of the Central Paratethys to the World Ocean (Bartol et al., 2014; ter Borgh et al., 2014). There is evidence supporting the prevalence of the connection to the Mediterranean Sea into the late Badenian (Bartol et al., 2014).

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NEW DISCOVERY OF MID-MIOCENE (BADENIAN) EVAPORITES INSIDE THE CARPATHIAN ARC – POSSIBLE IMPLICATIONS FOR GLOBAL CLIMATE CHANGE AND PARATETHYS SALINITY

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Prospecting for oil and gas on the Hungarian Great Plain led to the discovery of massive layers of evaporites in a deep depression of undisturbed sedimentation in the Soltvadkert Trough. The calcareous nannoplankton and foraminifera biostratigraphy indicated isochronous age with the classical well known BSC (Badenian Salinity Crisis) evaporites deposited from 13.8 Ma for a short period of 0.2-0.6 Ma (de Leeuw et al., 2010). This Hungarian occurrence is just part of the growing evidence of more evaporites inside the Carpathian Arc, e.g. East Slovakian Basin (Bukowski et al., 2007; Túnyi et al., 2005), Tuzla Basin (Ćorić et al., 2007), besides other Hungarian occurrences (Cserepes-Meszéna et al., 2000; Cserepes-Meszéna et al., 2004; Jámboer et al., 1976; Palotai and Csontos, 2012).

Based on our observations the Soltvadkert evaporites were formed in a deep, rapidly sinking basin with high sedimentation rates, where anoxia developed due to the oversaturated heavy hypersaline brine accumulating at the bottom of the basin. Inspired by the new evaporite occurrence, different scenarios were developed to explain the fate of evaporites inside the Carpathians (Fig. 1.). According to scenario A, where BSC evaporites found, they are just remnants of a once wide-spread evaporitic layer formed during the BSC in all deep basins of the entire CP (Central Paratethys). In this scenario evaporites were preserved in actively subsiding basins overlain by younger sediments accountable for protecting evaporites from recycling. However, according to scenario B, where we do not find evaporites inside the Carpathians, they became reworked later in the Badenian or Sarmatian, or just possibly overlooked in old seismic sections.

Scenario B sheds new light on the ‘myth’ of the brackish Sarmatian (Piller and Harzhauser, 2005) by explaining the origin of salt in hyper- or normal saline Sarmatian (Bitner et al., 2014; Cornée et al., 2009; Harzhauser et al., 2014; Tóth et al., 2010), by deriving salts from recycled BSC halite dissolving into the sea water.

Assuming wide spread massive evaporitic sedimentation for the whole CP area has implications for the Mid Miocene global cooling. This large amount of evaporites locked up in the CP might have lowered global salinity and triggered ice formation in polar regions contributing to global cooling, reflected in the Mi3 cooling event at the base of the Serravalian (Hilgen et al., 2012). The generally accepted view of eustatic control on the BSC evaporite formation by global cooling causing sea level drop and isolation might need reconsidering concerning causality.

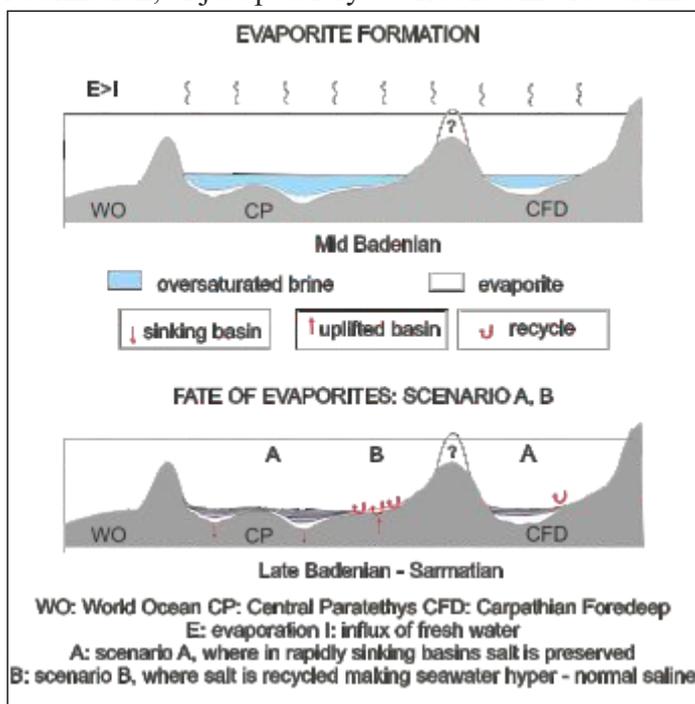


Fig. 1.: The fate of the BSC evaporites inside the Carpathian Arcs: according to scenario A evaporites were preserved in deep high sedimentation rates basins, while according to scenario B evaporites were recycled making Late Badenian or Sarmatian Sea hyper or normal saline.

The excess amount of evaporites believed to exist in the entire CP during the short period of BSC, might have initiated global cooling, calling for future studies to carry out mass balance calculations.

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BIOSTRATIGRAPHY AND PALEOENVIRONMENTAL EVOLUTION OF THE PANNONIAN (LATE MIOCENE) OF THE NORTH WESTERN REALM OF LAKE PANNON BASED ON PALYNOLOGICAL DATA

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During the Late Miocene a wide brackish lake, Lake Pannon formed in the Alpine-Carpathian-Dinaric realm covering the territory of the Pannonian Basin system. After its isolation from adjacent Paratethyan and Mediterranean areas during the Sarmatian, marine microplankton became extinct and new endemic forms originated.

These endemic dinoflagellate cysts play a crucial role in the biostratigraphic subdivision of latest Sarmatian-Pannonian deposits.

We analysed the dinoflagellate assemblages and terrestrial palynomorphs from 26 core samples from the Danube Basin in order to present preliminary data on the Pannonian, (late Miocene) dinocyst zonation for the Danube Basin (Slovakia) and correlation possibilities with other Paratethyan biozonations. Additionally, the facies evolution and vegetation patterns are studied based on organic-walled microplankton and sporomorphs. The Modrany (M-1) core contained the most complete microplankton assemblages, the other studied cores (Nová Vieska, Diakovce, Kolárovo, Dunajská Streda) provided only additional data.

Three zones were distinguished: in the early Pannonian the *Spiniferites bentorii pannonicus*-*Spiniferites bentorii oblongus* Zone and *Spiniferites bentorii coniunctus*-*Pontiadinium pecsvaradensis* Zone were distinguished and the early late Pannonian is represented by the *Spiniferites paradoxus* Zone. The first two zones are correlatable to the early Pannonian assemblages in Hungary and Croatia. The lack of the *Mecsekia* plexus in the lowermost Pannonian samples in Slovakia is in contrast to the abundance of this taxon in Hungary and Croatia. Its absence points to either a gap between the Sarmatian and Pannonian stages or questions the interregional feasibility of the Hungarian and Croatian zonations and suggests a very strong facies control on time equivalent microplankton assemblages. The signal of the late early Pannonian transgression of the lake is visible in the increasing number of proximate dinoflagellate cysts in the two older zones indicating open–more distal environments with regard to the former coastal line.

The youngest *S. paradoxus* Zone is equivalent with the early late Pannonian zones in Croatia and Hungary. These assemblages are very poor, host only few dinoflagellates indicating unfavourable habitats for dinocysts in the Danube Basin. Younger dinoflagellate assemblages were not recorded, as in the younger part of the late Pannonian the study area was filled up by fluvial sediments and smaller lakes only prevailed isolated from Lake Pannon.

In the pollen spectra from early Pannonian broad-leaved deciduous elements dominate with some thermophilous elements, e.g. *Engelhardia*, *Laevigatosporites* suggesting a warm-temperate climate and mixed mesophytic forests with deciduous oaks, *Pinus* and *Cathaya* together with abundant mountain conifers *Picea* and *Abies*. *Tsuga* is present in smaller proportions. Lowland vegetation is represented by *Alnus*, *Liquidambar* *Ulmus*, and indicating well-developed riparian forests and local swamps (*Cupressaceae*, *Myrica*).

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LAKE PANNON DELTAIC DEPOSITS IN GERECSÉ HILLS, HUNGARY

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The brackish water of the Late Miocene Lake Pannon is characterized by a long term normal regression, led by high rate of sediment input from emerging mountains around the basin. Deep basins got filled up by profundal marls, turbidites and slope shales, followed by shallow water deltaic bodies and alluvial plain deposits. In our study, we have focused on shallow-water successions.

The study area is located in the northern foreground of the Gerecsé Hills, near Neszmély. In the Disznóskút Valley there are well exposed outcrops, 11 within a 1km distance. The facies analysis and molluscs studies shows that the exposed Pannonian successions was deposited in shallow offshore waters and on the delta plain. The sedimentary successions reflect cyclic changes of these depositional environments. These lacustrine parasequences indicate repeated rises of base level. Some of the fluvial deposits could be channels on the delta plain, but those of a more complex cut-and-fill structure are interpreted as small incised valleys, related to minor drops of base-level.

This cyclicity was also detected in the boreholes and well logs. The position of these deltaic deposits and the measured paleotransport directions indicate that the Gerecsé block was not only a passive morphostructural feature flooded and covered by sediments, but its relative vertical motion may have actively influenced the locus of different sedimentary environments, incision of channels and sediment dispersal directions. In general, the northwestern Pannonian basin (i.e. the Danube basin) was filled by rivers coming either from the west (Alps), or from the Western Carpathians. The newly measured sediment transport towards N or NE may point to synsedimentary tilting of the Gerecsé block, which locally prohibited the general southerly or southeasterly transport.

The study was supported by *OTKA project 81530* and the “*Márton Áron Tehetséggyógyító Szakkollégiumi Program*” grant.

LOWER MIOCENE FRESHWATER DEPOSITS IN THE AREA OF KAŠINA, MEDVEDNICA MT., CROATIA

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Miocene clastic deposits crop out in a 3 km long succession along the road from Kašina to Laz Bistrički (Medvednica Mt.).

Base of the succession is represented with grey marls with molluscs, fish fragments, ostracods and land flora. Congerian coquina beds, 30 m wide, and with 10 to 30 cm thick beds, are the next exposure, before approaching the mountain ridge. Kochansky-Devidé & Slišković (1978) described several Dreisseniid taxa present in this area, including: *Congerina socialis* KOCHANSKY-DEVIDÉ & SLIŠKOVIĆ, *C. venusta* KOCHANSKY and others.

Near the mountain saddle, an interesting profile composed of 3 members is well exposed. Lower member is composed of marl with rich megaflora. Middle member is a 2-3 cm thick layer of finegrained, completely altered tuff. Upper member of the succession is again marl, with fossil flora and small Mollusca. Fragmented angiosperm leaves represent a mixture of subtropical and warm-temperate taxa.

Initial paleontological analyses indicate the existence of fluvial and lacustrine paleoenvironments in the Lower Miocene (Ottangian, Karpatian) of this area, and, can be compared with the neighboring locality Planina (Basch, 1983a, 1983b; Avanić *et al.*, 1995; Jungwirth & Đerek, 2000).

Detailed paleontological and sedimentological analysis is in progress, including the estimation of the absolute age based upon the minerals from pyroclastic layer.

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PRELIMINARY RESULTS OF INVESTIGATION OF THE PANNONIAN (LATE MIOCENE) MOLLUSCAN FAUNA FROM SEVERAL LOCALITIES OF THE TRANSYLVANIAN BASIN (ROMANIA)

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During the Late Miocene, an enormous and long-lived lake – Lake Pannon – covered most of the intra-Carpathian Basin System, including the Pannonian Basin proper and several smaller peripheral basins. One of such basins was the Transylvanian Basin, the water mass of which was probably connected to Lake Pannon north and/or south of the Apuseni Mountains, i.e. through the Szilágyság/Sălaj area and/or the Maros/Mureş Valley. Today, the Pannonian sediments constitute a more or less contiguous area in the southern part of the Transylvanian Basin.

Since the Late Cretaceous, more than 5 kilometres thick sedimentary succession has been deposited in some parts of the basin. This basin fill can be divided into four tectonostratigraphic megasequences: Upper Cretaceous rift basin, Paleogene post-rift phase (sag basin), Lower Miocene flexural fore-arc basin and Middle to Upper Miocene compressional back-arc basin (Krézsek & Bally 2006). Simultaneously with the uplift of the adjacent Carpathians, more than 3500 metres thick Badenian to Pannonian sediments accumulated in the Transylvanian Basin. After the complete infilling of the basin, tectonic inversion occurred and exhumation and erosion started at the end of the Miocene. As a result, deposits younger than 8-9 million years have been eroded (Sanders et al. 2002).

In the beginning of the Pannonian, deep-water environments prevailed in much of the basin. In contrast to older theories (Marinescu 1994, Magyar et al. 1999), investigation of sublittoral to deep-water marls near Oarba de Mureş demonstrated that sedimentation was continuous across the Sarmatian/Pannonian boundary, at least in the deeper parts of the Transylvanian Basin (Sztanó et al. 2005, Filipescu et al. 2011). These deep-water sediments are exposed today due to the intense erosion. In the western-south-western part mainly lacustrine fans are preserved. Sedimentation continued in shallow lacustrine and fluvial environment probably until the end of the Miocene. In the south-eastern part some 100 metres thick shallow-water (delta and fluvial) and freshwater/paludal formations are preserved below the Pliocene volcanics that protected the youngest Pannonian beds from erosion (Krézsek et al. 2010).

No detailed and comprehensive treatise has ever been published on the Pannonian molluscs of this basin. We collected the faunal lists of 31 localities from the Romanian and Hungarian palaeontological literature. These records contain altogether 138 taxa (this number is very low compared to the more than 900 species of the Pannonian Basin), including 15 species described as new ones (Lubenescu 1981, 1985, Lubenescu & Lubenescu 1976, Pana 1975). We collected molluscs from several localities (Vingard, Lopadea Veche, Tău, Mihălţ, Gârboviţa, Oarba de Mureş, Gârbova de Jos, Agârbiciu and Chibed), and compare them with the published data.

The fauna of 5 outcrops (Oarba de Mureş B, C, E, Chibed and Vingard) has been identified so far. In the grey calcareous clay of the Oarba de Mureş B outcrop 5 species („*Gyraulus*” *dubius* (Gorjanović-Kramberger), „*G.*” *praeponticus* (Gorjanović-Kramberger), „*Lymnocardium*” *praeponticum* (Gorjanović-Kramberger), *Orygoceras brusinae* Gorjanović-Kramberger and *O. levis* Gorjanović-Kramberger) were found. From the grey clay marl of outcrop C only one specimen of *Velutinopsis nobilis* (Reuss), while from the light grey calcareous marl of outcrop E many specimens of *Congeria banatica* R. Hörnes and „*L.*” *undatum* (Reuss) are available. These species indicate sublittoral or profundal depositional environment. The grey coarse sand of Chibed contains a lot of *C. banatica* and *Paradacna lenzi* (R. Hörnes), pointing to a profundal lacustrine environment. The Vingard locality – an outcrop consisting of yellowish grey fine sand – yielded the following taxa: *Melanopsis fossilis fossilis* (Martini & Gmelin), *M. magnus* Lubenescu, *Unio* cf. *mihanovici* Brusina, *Congeria* div. sp. and *Melanopsis* sp. This fauna obviously indicates a littoral nearshore environment.

With further collection and investigation of fossils, sedimentological field studies and revision of old fossil collections, our objective is to gain new information about the connection between the Transylvanian and the Pannonian Basins and to explore the palaeogeographical, palaeoenvironmental and palaeoecological context of the Late Miocene molluscan faunas.

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LAKE LEVEL FLUCTUATIONS AND VARIOUS DELTA TYPES IN A PANNONIAN (UPPER MIOCENE) SEDIMENTARY SEQUENCE AT HÍMESHÁZA (EASTERN MECSEK MOUNTAINS, SW HUNGARY)

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Late Miocene lacustrine deposits in the vicinity of the Mecsek Mountains, in the southern part of the Pannonian Basin, are relatively poorly known. Various lithological units, their sedimentary and structural features were studied in a sand pit in the Eastern Mecsek. The sandy sequence unconformably overlies Middle Miocene fossiliferous, pebbly limestones and lies next to the Carboniferous Mórággy Granite Formation. This latter was the main sediment source in the lower part of the Upper Miocene succession. The lacustrine sequence can be subdivided into three main facies associations. The lower facies association (ca. 20 m thick) consists of alternating beds of coarse-grained arkosic sand and gravel. Both contain granite derived angular clasts (feldspar, quartz and rock fragments). Limonitic moulds of littoral lacustrine molluscs were also found in these beds. Clay occurs as continuous beds or as irregular patches in the sand, and its abundance changes systematically, usually increasing upward. In the continuous beds the clay is mixed with very coarse sand to pebble-sized clasts in a matrix-supported fabric. These beds are interpreted as debris flow deposits, while the others as semi-cohesive grain-flows. The beds dip steeply and have opposite dip directions in the two halves of the sand pit. Syndepositional strike-slip faults and deformation bands were also observed in the lowermost unit. The second facies is represented by a 3 metres thick dark grey claymarl, with a rich assemblage of sublittoral molluscs. The third facies association overlies this with a sharp boundary. It is made up of ca. 20 m thick silty sand, without systematic vertical variation in the grain size. Structureless silty sands alternate with cross-laminated and cross-bedded sands. The bottom surface of the structureless sands shows irregular, wide or narrow pockets tapering downwards, indicating bioturbation. This facies association contains littoral lacustrine mollusks. Few centimeter thick gravel beds occur as intercalations, which again consist mainly of granite detritus. In this facies, however, the granite body was not the only source of clasts, as fragments of Middle Miocene limestones, conglomerates and characteristic Middle Miocene fossils like shark teeth are present.

The lowermost arkosic sand and gravel was deposited on a fan delta, which was built mainly by debris and grain-flows coming from islands or inundated structural highs made up of granite. The overlying clayey facies with sublittoral molluscs was deposited in water depths below the storm wave base and thus points to a base-level rise. The sharp boundary with the uppermost sandstone facies association may indicate forced regression, i.e. a rapid drop of the base level. This third facies association is interpreted as a possible spit/barrier bar or mouth bar sediment. The reduced amount of granite detritus in the middle (clayey) and the uppermost (sandy) facies association points to a temporal cut-off/backstepping of the granitic source area during their deposition. All mollusks indicate the same biozone, the *Prosodacnomya/Congerina rhomboidea* zone, with an age between 8 and ~6 Ma. This means that flooding of the area by the lake and the further base level changes happened during a relatively short time interval.

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MIOCENE TUFFITE LEVELS FROM NEW BOREHOLES BUSKO PIG-1 AND KAZIMIERZA WIELKA PIG-1, CARPATHIAN FOREDEEP (POLAND)

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Several tuffite levels were found in the Middle Miocene (Badenian-Sarmatian) evaporate-siliciclastic succession (Bukowski 2015; Czapowski, Gąsiewicz 2015) from two boreholes: Busko (Młyny) PIG-1 and Kazimierza Wielka (Donosy) PIG-1, drilled in the northern part of Carpathian Foredeep (Fig. 1). Mineral and petrographic composition of these tuffites were examined in polarizing microscope, the scanning electron microscope (SEM/EDS) and XRD methods. Chemical composition of whole rock samples was determined ICP-INAA methods. Research has shown that levels of tuffites differ from one another the chemical composition of glass, contain of alkaline plagioclases, individual components of the grain size and the presence of typical rock-forming minerals (e.g. biotite, pyroclastic quartz and potassium feldspar) and specially the occurrence of clay minerals such as Ca- and Na-smectite, illite and kaolinite. The occurrence of secondary minerals such as sulfur, Na-jarosite and zeolites have been identified. The normal gradations and lamination of tuffites indicates that they originated as a result of sedimentation of volcanic ash in the marine conditions. The degree of preservation of pyroclastic minerals in tuffites reflects changes in the geochemical environment of deposition. Two of numerous tuffite interbeds have been correlated. First level of tuffites located above evaporites (M1/1 and D1/1 see Fig.1) is the most widespread and has a characteristic chemical composition of pyroclastic components and it can be applied to the regional correlation. The upper one (M1/2 and D1/2 see Fig.1) is located above the registered normal (C5AAn) to reversed (C5Ar.3r) polarity change (Sant *et al.* 2015).

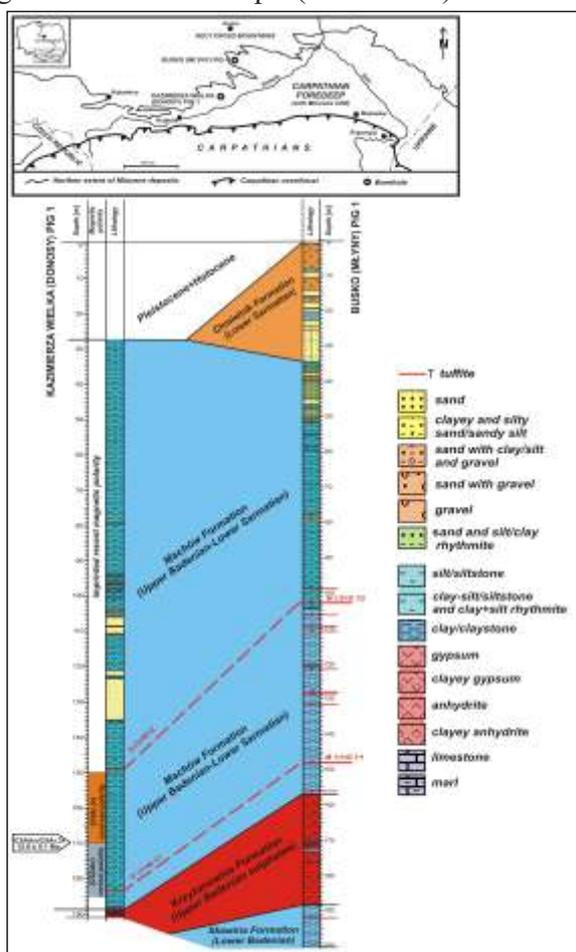


Fig.1.: Location and lithostratigraphic profiles of the Busko (Młyny) PIG-1 and Kazimierza Wielka (Donosy) PIG-1 boreholes. In figure indicated levels of tuffites and magnetic polarity for the Kazimierza Wielka (Donosy) PIG-1 borehole (Czapowski, Gąsiewicz 2015; Sant *et al.* 2015).

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PALEOICHOLOGY OF A BADENIAN ROCKY SHORE

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Remains of Middle Miocene age fossil rocky shore are exposed at the western part of Mecsek Mountains. The locality is situated at the vicinity of the village Hetvehely along the railroad section No. 1895. Geographical coordinates of the locality are: 46°07'59.12"N, 18°02'54.21"E.

The rocks of the former coast belong into the Viganvár Limestone Member of Hetvehely Dolomit Formation.

There have been 67 bioeroded limestone slabs collected at the locality. Their length vary between 2 and 25 centimeters.

Table 1.: The observed trace fossils and their producer organisms; Hetvehely, Mecsek Mountains

ICHNOTAXA	ETOLOGY	PRODUCER
<i>Entobia geometrica</i> BROMLEY - D'ALESSANDRO, 1984	Domichnia	<i>Cliona celata</i>
<i>Entobia laquea</i> BROMLEY - D'ALESSANDRO, 1984	Domichnia	<i>Cliona vastifica</i>
<i>Renichmus arcuatus</i> MAYORAL, 1987	Fixichnia	Vermetidae
<i>Caulostrepsis</i> isp.	Domichnia	Polychaeta
<i>Maeandroplydora elegans</i> BROMLEY - D'ALESSANDRO, 1988	Domichnia	Polychaeta
<i>Trypanites solitarius</i> (HAGENOW), 1840	Domichnia	Sipunculidae
<i>Gastrochaenolites lapidicus</i> KELLY - BROMLEY, 1984	Domichnia	<i>Lithophaga</i> sp., <i>Hiatella</i> sp.
<i>Gastrochaenolites torpedo</i> KELLY - BROMLEY, 1984	Domichnia	<i>Lithophaga</i> sp.
<i>Gastrochaenolites cluniformis</i> KELLY - BROMLEY, 1984	Domichnia	<i>Lithophaga</i> sp.
<i>Gastrochaenolites orbicularis</i> KELLY - BROMLEY, 1984	Domichnia	<i>Lithophaga</i> sp.
<i>Rogerella pattei</i> (SAINT-SEINE, 1954)	Domichnia	Acrothoracica

Some characteristic trace fossils of the locality are shown in Figs. 1-4.

The bioerosion took place among marine circumstances at the littoral region. Two levels of the bioerosion can be distinguished according to the position and frequency of the trace fossils. It refers to gradual, small scale transgression.



Fig. 1.: Entobia laquea, epoxy cast



Fig. 2.: Gastrochaenolites torpedo



Fig. 3.: Maeandropolydora elegans apertures

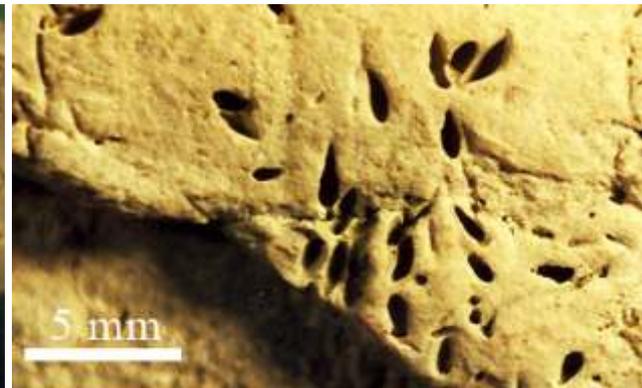


Fig.: 4. Rogerella pattei

**PALEOMAGNETIC AND GEOCHRONOLOGIC CONSTRAINTS ON THE
MIOCENE EVOLUTION OF SEMI-ISOLATED BASINS IN
SOUTHEASTERN EUROPE**

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Chronostratigraphic control on the Paratethys regional stages remains rudimentary compared to the cyclostratigraphically-constrained Mediterranean stages. This lack of chronostratigraphic constraint restricts insight into the timing of geodynamic, climatic, and paleobiogeographic events and thereby hinders the identification of their causes and effects. Over the past decade, however, much progress has been made. Here, we will provide an overview of magnetostratigraphic and radio-isotopic ages for some Badenian, Sarmatian and Pannonian deposits of the Transylvanian Basin, the Pannonian Basin, the Carpathian Foreland Basin and the intra-montane basins of the Dinarides. We will integrate these into the regional chronostratigraphic framework and discuss some of the implications.

COMPOSITIONAL CHANGES OF MOLLUSCAN ASSEMBLAGES DURING THE LATE BADENIAN AND EARLY SARMATIAN IN THE NW VIENNA BASIN (MALE KARPATY MOUNTAINS, SLOVAKIA)

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Middle Miocene marine sediments in the Vienna Basin provide opportunities for multivariate analyses of variation in taxonomic and life-habit composition of molluscan assemblages across the Badenian/Sarmatian boundary. Although a major sea level fall took place at this in the Vienna Basin, deeper depocenters in the Vienna Basin can record relative continuous successions spanning this boundary. Diverse molluscan assemblages in this area were described by Švagrovský (1971, 1981), Meszároš (1986) and Hladilová (1991), but temporal quantitative changes in community composition remain poorly known.

Samples analyzed in this study come from 80 closely-located borehole cores near Rohožník-Konopiská (NW Vienna Basin, Male Karpaty Mountains, Slovakia), penetrating to ~30-100 m depth. These cores capture sediments of the Studienka (Upper Badenian) and Holíč (Lower Sarmatian) formations that consist of clays, sands and silts. A well preserved shelly material from these samples contains presently more than 6000 individuals (mainly of Upper Badenian age), with ongoing screening of additional samples. They correspond to 156 gastropod, bivalve, and scaphopod taxa at species and genus-level resolution. 72 samples were subjected to preliminary multivariate analyses in the R language. A cluster analysis is based on a Bray-Curtis distance and square-root transformed proportional abundances. Ordination analyses are represented by non-metric multidimensional scaling and by principal coordinate analysis.

The cluster analysis discriminated four major groups of Upper Badenian assemblages. The first group is dominated by an infaunal deposit-feeder *Nucula nucleus* (a species that was probably well-adapted to sea-floor conditions with low-oxygen concentrations) and a carnivorous predator *Nassarius illovensis*. The next group of samples is dominated by an infaunal suspension-feeder *Corbula gibba*, which represent opportunistic species that preferred muddy bottoms, frequently also with low-oxygen concentrations and high content of organic matter. The third group of samples is dominated by *Acanthocardia turonica*, *Turritella badensis* and *Cardites partschi*. The fourth group of samples by *Turritella erronea*, *Diloma orientalis*, and *Jujubinus exasperatus*. The species in the latter two groups tend to prefer sandy bottoms and reflects shallower environments than those dominated by *Nucula nucleus* and *Corbula gibba*. This discrimination of samples fits with the result of R-mode PCA and NMDS where these species group similarly. Bivalves indicate that sedimentation occurred in a shallow subtidal, relatively protected environment (below storm wave base) during the Late Badenian. The high abundance of *C. gibba* and *N. nucleus* and rarity of epifaunal components shows a possibility of stratification of water column during the Late Badenian, with low content of O₂ within and on the sea-floor. Lower Sarmatian assemblages are dominated by *Mohrensternia pseudosarmatica*, *Mohrensternia pseudoinflata*, *Mohrensternia inflata*, *Rissoa certa*, *Bittium reticulatum deforme*, and *Cerithium politioanei*. They show a higher compositional heterogeneity than Badenian assemblages and presently do not simply cluster into well-defined sample groups (this pattern can change with analyses that are in progress).

In ongoing analyses, we plan to test whether bivalve assemblages from the Badenian and Sarmatian stages significantly differ in their taxonomic and life habit composition, and whether changes in the turnover of molluscan communities coincides with turnover in foraminiferal communities (as distinguished on the basis of foraminiferal assemblages by Čierna (1974)).

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PROBLEMS IN IDENTIFYING THE KARPATIAN-BADENIAN BOUNDARY IN THE ALPINE-CARPATHIAN FOREDEEP OF AUSTRIA AND THEIR POSSIBLE OVERCOME BY USING CHANGING CLIMATE-INDUCED FORAMINIFERAL COILING DIRECTIONS

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Sediments of the Laa- (Karpatian) and Grund- (Badenian) Formations are very similar (marls, sand(stone)s, partly conglomeratic) and can only be distinguished by its fossil content. Microfossils play a mayor role for the determination of the deposition period. Ostracods are very rare in standard samples and no nannoplankton zonal boundary can be found in the Karpatian-Badenian interval. Among planktic foraminifera, the occurrence of *Praeorbulina* and *Orbulina* characterizes Badenian sediments. Several species of benthic *Uvigerina* and *Pappina* are thought to occur in Karpatian or Badenian deposits only. However, these assumptions are not valid or not applicable in many if not most cases. Stratigraphic ranges of *Uvigerina* and *Pappina* are longer than previously thought. Furthermore, similar to *Praeorbulina* and *Orbulina*, most potentially index fossil bearing samples do not contain many of these taxa or do not contain any of them. I.e., in a Badenian core, many samples do not yield *Praeorbulina* or *Orbulina*. Apparently, the presence of many if not most taxa from this variable marine environments is depending from local or short-living environmental changes. Thus, the need for alternative approaches is evident.

Here, we present an old approach which has been neglected for a long time. Since the coiling direction of many foraminiferal taxa (e.g., *Neogloboquadrina*) is temperature related and the significant and fast temperature rise towards the Middle Miocene climate optimum took place during the interval of interest, we intent to apply the change in coiling ratios of selected, frequent and easily to identify taxa for stratigraphic purposes. From a small set of pilot samples with well known ages, we counted left and right coiled *Globorotalia bykova* (planktic) and *Ammonia* spp. (benthic) individuals. Our results show a drop from 53-66% right coiled *G. bykova* from Karpatian to 34-52% from Badenian samples. Also among *Ammonia* spp., we found a drop from 18-25% right coiled (Karpatian) to 5-9% (Badenian). Although the reasons for the observed phenomena are yet unknown, we found our initial results very promising and hope for a fruitful discussion during the workshop before the launch of a larger research project on the topic.

EARLY MIOCENE DEPOSITS IN NORTH CROATIA (SLAVONIA) - REVIEW OF THE WORK AND RESULTS

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This study is based on a compilation of published and unpublished data from Early Miocene deposits of North Croatia. Generally, the main work and results refers to the North Croatian Basin in the area of Slavonia.

The formation of the sedimentary basin in the North Croatia started in the Early Miocene, probably in the Otnangian (Pavelić et al., 1998; Pavelić & Kovačić, 1999; Pavelić, 2001) or Karpatian (Kovačić et al., 2011). Alluvial sediments are overlain by lacustrine freshwater to brackish deposits in which abundant ostracod assemblages are found (Hajek-Tadesse et al., 2009). Marly and sandy sediments of an oligotrophic freshwater lake contain specific ostracod assemblages and mollusc's faunas. The non-marine ostracod fauna from the oldest Early Miocene Lake in Croatia is autochthonous, and well preserved. The general population structure of the lake ostracod fauna indicates low water energy of the environments and low sedimentation rates. Based on the sporomorphs, sedimentation occurred in a warm subtropical climate (Nagy, 2005; Pavelić et al., 2003). In sporomorphs assemblage tropical spores are dominant: *Cicatricosisporites*, *Echinatisporites*, *Polypodiaceoisporites* and *Osmundacidites*, although subtropical spores *Leiotriletes*, and temperate pollen *Caryapollenites* and *Bisaccites* are also abundant. The *Heliospermopsis*, the salt glands of mangrove plants, are found in the youngest samples. It points out to some salinity in the lake. According to Hajek-Tadesse et al. (2009) the increase of water salinity was caused by the ingression of marine water into the lake. Ingression of marine water was documented by the composition of ostracod fauna, and scarce foraminifers. Lacustrine conditions were replaced by marine environments. Pikija et al. (2005) recorded exchanges of freshwater lake and marine sediments in the upper part of Tuk formation of the Dilj Mt. The continuing contact between brackish and marine sediments has been noticed in the Mt. Požeška gora, and in another location on the Mt. Požeška gora tuffs and tuffites were deposited over brackish sediments. These sediments contain diatom assemblage with *Coscinodiscus*, *Gramatophora*, *Diatom* and *Paralia* species, which come together with very rare appearance of Badenian marine species *Diploneis didyma*, *Pseudopodosira witty*, *Rhaphoneis fusiformis*, *Opephora gemmata* and *Pterotheca reticulata*.

In investigated area first marine Badenian marls is indicated by the presence of the planktonic benthic foraminiferal assemblages in which the prevailing species are: *Cassigerinella* cf. *globulosa*, *Globigerinoides trilobus*, *Globigerina otnangiensis*, *Globigerina praebulloides*, *Globigerina tarchanensis*, *Globigerinita uvula*, *Tenuitellinata selleyi*, *Tenuitellinata angustiumbilitata*, *Turborotalita quinqueloba*, *Svratkina cichai*, *Valvuneria complanata*, *Sigmoilinita tenuis*, *Coryphostoma digitalis*, *Hanzawaia boueana*, *Cibicidoides ungerianus*, and very rare species are from *Bulimina-Bolivina* group. In the marine deposits *Cribroperidinium tenuitabulatum* assemblage zone (Jiménez-Moreno et al., 2006; Bakrač et al., 2012) has been documented using palynomorph assemblage. At the Mt. Papuk marine sediments of the Karpatian age are overlying freshwater beds (Pavelić et al., 1998). Based on nannofossil assemblages first marine transgression in the Mt. Papuk after Ćorić et al. (2009) corresponding to the NN5 zone.

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THE NEOGENE TO QUATERNARY VOLCANISM IN THE CARPATHIAN-PANNONIAN REGION: DOES THE PLATE TECTONIC CONCEPT WORK HERE?

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Since the end of 1960's the plate tectonic concept has provided a solid framework to explain the geodynamic processes on our planet. Most of the volcanic activities can be linked to plate boundaries and composition of the erupted magmas is largely dependent upon the plate tectonic setting. Basalts with MORB (=Mid Ocean Ridge Basalts) composition are conventionally linked to oceanic ridges along the borders of spreading plates, whereas andesitic and dacitic rocks with calc-alkaline compositional trends are commonly thought to define subduction zones. Alkaline basalts and some tholeiitic basalts occur, however, at intra-plate areas and explanation of their origin was difficult to constrain by the plate tectonic model. Nevertheless, this apparent problem was solved also quickly by the introduction of the hot-spot and plume concepts. In summary, it appears that there is a good relationship between composition of igneous rocks and the plate tectonic setting and this can be used effectively to reconstruct geodynamic processes in the past.

Although the plate tectonic concept works quite well in a global scale, its conventional application in a smaller area often encounters some problems. The formation and evolution of the Pannonian Basin is accompanied by eruption of various magmas. They can be classified into four main groups: (a) silicic pyroclastic rocks; (b) calc-alkaline andesitic to dacitic, occasionally rhyolitic volcanic suites; (c) alkaline basalts; (d) ultrapotassic rocks. Based on the compositional diversity of the volcanic products we can suggest that this region could have been located at a convergent plate margin and subduction played a major role in the geodynamic evolution. Group (a) and (b) can be easily linked to this process. If we consider the origin of the alkaline basaltic magmas, lithospheric extension and mantle plume activity seem to be the most plausible explanation. The ultrapotassic rocks are rare volcanic products of magmatic activity and their unusual composition is generally attributed to the small degree melting of lithospheric mantle containing metasomatized veins. This can occur either due to the thinning of the lithosphere (decompression melting) or to the heating of upwelling mantle material such as plume. Thus, subduction, lithospheric extension and mantle plume appear to be the main major controlling mechanisms that could have operated in the Carpathian-Pannonian region (CPR). However, going into the details, we can quickly realize that the answers to the principal geodynamic questions are not as simple as we thought and in addition, we have to find other explanation what the plate tectonic concept offers.

Considering the temporal evolution of the volcanic eruptions, the spatial distribution of the volcanoes as well as the compositional variation of the volcanic rocks, we can conclude that lithospheric extension of the Pannonian Basin could have a major – direct and indirect – role in the magma generation. The Miocene silicic and the calc-alkaline volcanism at the northern part of the Pannonian Basin are closely related to the syn-rift event. The silicic volcanism could be classified as a bimodal intra-continental volcanic activity, where mantle-derived basaltic magmas had an important petrogenetic role. They initiated extensive melting in the thick lower crust resulting in silicic magma batches, which developed large volume magma reservoirs in the continental crust. New zircon dating suggests an ignimbrite flare-up period between 18 and 14 Ma, when several tens of cubic kilometre of dacitic to rhyolitic magmas erupted and formed devastating ignimbrites. This required a strong heating of the continental crust that could contribute to the crustal thinning.

At the western segment of the Carpathian arc (northern part of the Pannonian Basin), imitation of the calc-alkaline volcanism was just coeval with the beginning of the main rifting phase (16-17 Ma) and there are evidences for syn-volcanic extension at many areas. Eruption of rare rocks types, i.e. garnet-bearing andesites and rhyodacites could indicate the change in the stress field

from compressional to tensional. Compositional changes of the calc-alkaline volcanic rocks can be interpreted as initial mixing of mantle derived mafic magmas with melts from the metasedimentary lower crust followed by an increase of asthenospheric mantle input in the melt generation process. These are more consistent with an environment of gradually thinning lithosphere than a coeval subduction. In this scenario, the 'calc-alkaline' signature is just a reflection of the nature of the magma source region what could be primarily the lithospheric mantle metasomatized by subduction-related fluids in the past. In the eastern part of the CPR, calc-alkaline volcanic rocks could be better linked to subduction processes. However, the supposed retreating subduction was not associated with coeval volcanism even along this segment of the Carpathian arc. Instead, the volcanic activity took place always during a post-collisional phase. In this context, it is still a question how the vertical slab beneath the Vrancea zone can be explained, i.e. the latest stage of subduction, slab detachment or slab delamination? Understanding the geodynamic background of this event is crucial to evaluate the related seismic and volcanic risk.

Alkaline basaltic volcanism has been taking place in the Carpathian-Pannonian Region since 11 Ma and the last eruptions occurred only at 100-500 ka. It resulted in scattered low-magma volume volcanic fields located mostly at the margins of the Pannonian basin. There are no convincing evidences for the existence of mantle plume or plume fingers beneath this region, nor coeval progressive lithospheric extension. However, plate tectonic processes could have indirectly controlled the magma generation. The Pannonian basin was formed by major lithospheric thinning during the Mid-Miocene. Thus, it acted as a thin-spot after the syn-rift phase and provided suction in the sublithospheric mantle, generating asthenospheric flow from below the adjoining thick lithospheric domains. A near vertical upwelling along the steep lithosphere-asthenosphere boundary beneath the western and northern margin of the Pannonian basin could result in decompressional melting of the strongly heterogeneous asthenospheric mantle and this produced low-volume melts. The youngest basalt volcanic field (Perşani) is inferred to have been formed due to the dragging effect of the descending lithospheric slab beneath the Vrancea zone that could result in narrow rupture at the base of the lithosphere. New melting models allow constraints also on the depth of the lithosphere-asthenosphere boundary beneath the Pannonian basin.

Understanding of the mechanisms operated during the formation and evolution of the Pannonian basin as well as explanation of the related volcanism are still challenging tasks, but could greatly help to have a better understanding on how the Earth works. Based on the present observations and data, we can conclude that continuation of the volcanic activity in the Carpathian-Pannonian region cannot be excluded in the future as inferred from the still fusible condition of the asthenospheric mantle and the active geodynamic processes in the east Carpathians resulted in the formation of the youngest, 200-32 ka Ciomadul volcano.

A WORLD OF LAKES - EUROPEAN NEOGENE FRESHWATER SYSTEMS

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We propose a paleobiogeographic framework for European Cenozoic freshwater systems. The distribution of 2,226 species-group taxa of freshwater gastropods from over 2,700 Miocene and Pliocene localities was evaluated. The localities were grouped into paleo-freshwater systems based on latest paleogeographic reconstructions. Cluster analyses were computed for four time slices, i.e., Early Miocene, Middle Miocene, Late Miocene, and Pliocene. The analyses demonstrate a generally high degree of provincialism for the Neogene freshwater systems and allow the definition of biogeographic units, based on the cluster analyses, the degree of endemism, and geographical coherence. The resolution of the subdivisions increases with time. The Early Miocene is characterized by a relatively low degree of provincialism suggesting the distinction of three regions. Coinciding with the development of many endemic systems on the Dinarian-Anatolian Island and in Central Europe, the Middle Miocene demonstrates a higher degree of provincialism, allowing the definition of six biogeographic regions. With the onset of the Late Miocene the retreat of the Central Paratethys and development of the huge Lake Pannon massively shaped faunal evolution and palaeobiogeography in general. The formation of the 'Lago-mare' environment fringing the Mediterranean Basin as well as the development of several restricted freshwater systems in Western Europe additionally promoted biogeographic division. The increasing provincialism allowed the delimitation of six biogeographic regions, three of which could be subdivided into seven dominions. With the disappearance of Lake Pannon and the decline of western European and Mediterranean faunas at the Miocene-Pliocene boundary, biodiversity hotspots shifted toward eastern and southeastern Europe. For the Pliocene four biogeographic regions, five dominions, and four provinces were defined.

The large-scale changes of the community composition on the family level, differences of the relative species richnesses per biogeographic regions and the rising rate of endemism are all largely controlled by the varied presence of long-lived lakes. The underlying mechanism for this pattern is the ongoing continentalization of Europe triggered by the Alpidic Orogenesis and the simultaneous retreat of the Paratethys Sea. As shown by the alternation of the biogeographic regions through time, the changing shorelines of the Paratethys had a massive impact on the evolution of surrounding freshwater systems. The successive restriction of this huge intercontinental sea from the Mediterranean promoted the evolution of endemic freshwater faunas as similar to the marine realm.

**MICROVERTEBRATES FROM THE TYPE SECTION
OF THE KOZÁRD FORMATION
(MIOCENE, SARMATIAN) (N. HUNGARY, NÓGRÁD COUNTY)**

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The type-section of the Kozárd Formation is North of the village of Kozárd, by the road leading to Nagymező-pusztá. The lithostratigraphical unit was described by Hámor (1985). He classified Sarmatian coastal and shallow marine sediments as members of the unit. The limestones, calcareous sands and marls of the Kozárd section are extremely rich in fossil molluscs. This fauna was studied by Boda (1959, 1974). He listed the following species:

Lamellibranchiata: *Modiolus incrassatus*, *M. sarmaticus*, *Cardium vindobonense vindobonense*, *C. politioanei suessiforme*, *Irus gregarius*, *Ervilia trigonula*, *E. dissita dissita*, *E. dissita podolica*, *E. dissita crassa*, *Abra reflexa*, *Solen subfragilis*.

Gastropoda: *Calliostoma sturiacum*, *C. guttenbergi*, *C. angulatum*, *C. gradaespirum gradaespirum*, *C. papilla*, *Gibbula picta*, *G. biangulata*, *Rissoa mucronata*, *Mohrensternia inflata*, *M. pseudoinflata*, *M. multicostrata*, *M. hydrobioides*, *M. pseudoangulata politioanei*, *M. styriaca*, *M. restecostata*, *Moesia soceni*, *Pirenella picta picta*, *P. picta mitralis*, *Retusa truncatula*, *Actrocina lajonkaireana lajonkaireana*, *Clithon pictus pictus*, *C. pictus striatus*, *Valvata pseudoadeorbis*, *V. soceni wiesenensis*, *Hydrobia frauenfeldi*, *H. stagnalis stagnalis*, *H. stagnalis suturata*, *H. soceni*, *Bithynia tentaculata*, *Monacha punctigera*.

The Foraminifera fauna was studied by Jankovich and Koreczné Laky in Hámor (1985). They listed the following taxa:

Quinqueloculina implexa, *Q. seminula*, *Q. costata*, *Q. subcarinata*, *Q. reussi*, *Q. odessae*, *Q. circularis*, *Q. akneriana*, *Q. collaris*, *Q. pseudocostata*, *Massilina secans*, *Spiroloculina okrojantzki*, *Hauerina compressa*, *Triloculina lauta*, *T. consobrina*, *T. inflata*, *T. gibba*, *Nodophthalmidium sarmaticum*, *Nubecularia cristellaroides*, *Astrononion stelligerum*, *Elphidium rugosum*, *E. flexuosum*, *E. josephinum*, *E. macellum*, *E. georgium*, *E. reginum*, *E. hauerinum*, *E. macellum var. aculeatum*, *E. aculeatum*, *E. crispum*, *E. advenum*, *Discorbis valvulata*, *D. obtusa*, *Rotalia becarii*.

Up to 2014 vertebrate finds had not been reported from the Kozárd section. In 2014 the author found a 20 cm thick dark grey diatomaceous layer containing carbonized plant remains and mollusc shells. It is presumed that this layer was deposited during a regression, in marshy environment. The screenwashing of the sediment produced the following microvertebrate material.

Herpetofauna. (studied by Márton Venczel)

Pelobates sp., *Bufo* cf. *viridis*, *Pseudopus* sp., *Lacertidae* indet., *Colubridae* indet.

These taxa reflect dry biotope with bushy, grassy environment.

Rodents (studied by the author) *Albanensia albanensis* (Major, 1893), *Miopetaurista* sp., *Spermophilinus bredai* (Meyer, 1848), *Muscardinus* cf. *sansaniensis* (Lartet, 1851), *Myoglis meini* (De Bruijn, 1966), *Cricetodon* cf. *klariankae* (Hír, 2007), *Megacricetodon minor* (Lartet, 1851), *Democricetodon* sp.

The majority of the rodent taxa reflect humid forest environment. We can classify the fauna as belonging to the MN7/8 zone. The importance of the Kozárd vertebrate finds is their interbedded position into a marine section with rich invertebrate fauna. This fauna opens the door for the harmonization of the traditional Paratethys stratigraphy and vertebrate biochronology.

Tóth & Csoma (2015) (Eötvös University, Paleontological Department) studied the Foraminifera and Ostracoda fauna of a small sample taken exactly from the vertebrate bearing layer of the Kozárd section. They classified *Elphidium reginum*, *Elphidium fichtelianum*, *Elphidium crispum*, *Quinqueloculina akneriana* which refer to the early Sarmatian *Elphidium reginum* zone

Among the Ostracoda the *Aurila mehesi* and the *Cytheridea hungarica* are the index fossils of this zone.

Among the Sarmatian vertebrate faunas of the Carpathian Basin which were studied during the last decade Gratkorn (Austria) refers to the *Elphidium hauerinum* zone, while Varciorog (W. Romania) to the *Elphidium reginum* zone (Gross et al 2014, Filipescu et al 2014).

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REVISION OF HOLOSTRATOTYPUS AND FACIOSTRATOTYPES OF THE MORAVIAN FROM THE CZECH AND SLOVAK REPUBLIC (OSLAVANY, ŽIDLOCHOVICE, CHĽABA, SALKKA): MULTIPROXY STUDY

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The Moravian holostratotype Oslavany (the Carpathian Foredeep) and four faciostratotypes (sections Židlochovice, Borač in the Carpathian Foredeep and drills ŠO-1 Chľaba and K-5 Salka in the Danube Basin) have been defined in the territory of former Czechoslovakia (Papp et al., 1978). In the seventies of the last century, sections were processed at top level, but data collected at this time are now insufficient. Especially detailed quantification of changes in fossil assemblages as well as geochemical data are lacking. Unfortunately, the original section Židlochovice is covered by rock debris, allochthonous microfossils strongly prevailed in section Oslavany and material from K-5 Salka drill is most likely lost. Therefore five shallow boreholes were drilled and analysed in detail: drills ZIDL-1 and 2 in Židlochovice area (Doláková et al. 2014), drills OV-1 and OV-2 from Oslavany area supplemented by new sedimentological and taphonomical analysis of the original stratotype section (Nehyba 2014, Nehyba et al., in prep.) and drill LOM-1 situated near the Borač section (Holcová et al., submitted). In the Danube Basin, drill ŠO-1 is newly studied (Holcová and Fordinál, in prep.) and ⁸⁷Sr/⁸⁶Sr age was determined (Fordinál et al., 2014).

Methods: Lithofacies analysis, heavy mineral compositions, gamma spectrometry, in Oslavany area also ground penetration radar profiles were summarized for study sections. Paleobiological characteristics included quantitative analysis of palynomorphs, calcareous nannoplankton, foraminifera, molluscs, otoliths, in Židlochovice drills also red algae, Bryozoa and Ostracoda, in Oslavany drills Dinoflagellata. Carbon and oxygen isotopic analyses of foraminifera tests have been concentrated on study of detailed differences within paleobiotops (Scheiner, in prep.).

Stratigraphy: All studied drills can be biostratigraphically correlated with interval from the FO of *Orbulina* (14.6 Ma) to the LO of *Sphenolithus heteromorphus* (13.5 Ma). The LCO of *Helicosphaera waltrans* (14.3 Ma) accompanied by increase of *H. walberdorfensis* were recorded in the OV-1 and LOM-1 borehole. The FO of *Mendicodinium robustum* (about 14 Ma) was determined in the OV-1 borehole. Rare finding of *H. waltrans* in the well ŠO-1 is interpreted as redeposition, in spite of this interpretation, it indicates the presence of zones NN5a in the Danube Basin. ⁸⁷Sr/⁸⁶Sr datum for ŠO-1 borehole was calculated as 13.58-13.91 Ma (Fordinál et al. 2014) what agrees with the uppermost part of NN5 Zone.

The Styrian tectonic phase caused absence of TB2.3. cycle (with globally high sea-level during the MMCO) in the study area. The far-spread transgression recorded in the studied sections was caused by both global sea-level cycle TB 2.4. and forebulge subsidence. However, the recognized high-frequency T cycles were climatically controlled.

Paleoenvironments A mainly subtropical character of terrestrial flora was recorded. Within this framework, either warm humid conditions with seasonal increases, or cooler phases were observed. Accumulation of bisaccate conifers were observed in many of Lower Badenian cores from Carpathian Foredeep. Periodic changes of oryctocoenoses with diversified pollen spectra followed by a strong dominance of conifers together with marine dinoflagellates and, afterward, the disappearance all of pollen and spores were recorded in same time in boreholes ZIDL-1, 2 and OV-1. Above that succession, limestone layers were recorded (Doláková et al. 2014). Conifers over-representations were typical for oligotrophic conditions and climatic instability.

Marine organisms generally indicated a normal marine, warm to subtropical environment. The alternation of thick red-algal limestone bodies (a stable shallow paleoenvironment with low terrigenous input and sea-grass meadows) and variegated sandstone, mudstone and limestone

interbeds (in an unstable deeper environment) reflects orbitally-forced climatic cyclicity in the inner to outer shelf in ZIDL 1, 2 and ŠO-1 drills. Shelf in Oslavany area was characterized by fully clastic deposition. Thin interbeds of sandy and heterolithic facies represent most probably evidence of storm events. The holostratotype section Oslavany recorded rare beach environment with prevailing reworked fossils. Quiet environment of the outer shelf to upper bathyal of monotonous clayey silts was interpreted for LOM-1 drill, what is typical for the proximal parts of peripheral foreland basin.

Record of the Middle Miocene Climatic Transition (MMCT) The beginning of the Middle Miocene Climatic Transition can be correlated with the LCO of *Helicosphaera waltrans*. The transition started by storm events connected with heavy rainfalls followed by abrupt decrease of nutrient input, gradual increase of interannual as well as seasonal variability. Interannual oscillations of nutrient content, temperature and/or salinity are expected from oscillations of geochemical as well as paleobiological data.

The changes include cooling, aridification, decrease of nutrients, increase of salinity of superficial water and increase of seasonality, mainly seasonality of rainfalls. Seasonality in marine realm was manifested by alternation of mixed and stratified water with seasonal input of nutrients. Both sources (riverine input and seasonal upwelling) are possible. Increased salinity at the upper layer of water column signalled the processes leading to the “Wieliczian salinity event”.

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MACROSTRATIGRAPHY AND GEODYNAMICS OF THE PANNONIAN BASIN

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This talk deals with the regional-scale stratigraphic architecture of the Pannonian basin deduced from seismic and borehole data complemented with geological maps. Remarkable tectonic deformations of coeval depositional surfaces (timelines) will be shown and speculations on the geodynamics behind presented.

The Pannonian basin in eastern Central Europe constitutes an integral part of the Alpine orogenic system. The Alpine, Carpathian and Dinaric mountains surround this sedimentary basin of Miocene through Quaternary age. The basin is superimposed on two distinct orogenic terranes (Alcapan and Tisza-Dacia) derived from different paleogeographic position of the Alpine orogenic system.

Lateral extrusion of the Alcapan and Tisza-Dacia terranes from the East Alpine and Dinaric continental collision zones resp. occurred from Late Oligocene to Middle Miocene toward the Carpathian embayment characterized by “oceanic” lithosphere. Subduction and rollback of this lithosphere initiated the formation of the Pannonian basin in the Early Miocene. The peak period of extension was the Karpatian to Sarmatian time, when the main structural pattern of the basin was established.

After consumption of all subductible lithosphere in the Carpathian embayment further extension diminished and eventually terminated. The Pliocene through Quaternary has been a period of stress field change towards a compressional regime generated by the counterclockwise rotation of Adria. A fragmented Miocene/Pliocene unconformity can be recognized in the basin and its position indicates thousand meter scale differential movements during the Pliocene and Quaternary. The present fairly smooth topography of the Pannonian region suggests that fast erosion of uplifting areas (the “island mountains” and hilly lands) has fed the sinking basins (flat lowlands).

Upper mantle flow system has been shown to be responsible for generating dynamic topography in the Mediterranean region. The static value of the average topography relative to the reference level can be calculated by the assumption that a lithospheric column floats freely within the asthenosphere. The difference between the actual and static topography in the Pannonian basin turns out to be as high as 1000 meters. This differential (residual) topography is thought to be a dynamic feature explained in terms of instantaneous mantle flow due to temperature anomalies.

Differential movements during the Pliocene and Quaternary and their spatial distribution in the Pannonian basin have been interpreted as a consequence of stress field change from extension to compression in early Pliocene. Modeling results predicted quite well the observed spatial pattern, but the amplitude of stress induced deflections was much smaller than the observed thousand meter scale movements. More sophisticated numerical simulations have led to better predictions, but still far from a reasonably good agreement with observations. Elaboration of better geodynamic models is a vital issue of future research activity.

Additional information

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STRATIGRAPHICAL POTENTIAL OF FORAMINIFERA AND CALCAREOUS NANNOPLANKTON IN THE UPPER BADENIAN AND SARMATIAN SEDIMENTS OF CENTRAL PARATETHYS

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In the scope of the APVV project (DANUBE) we show here reevaluation of the mentioned sediments based on foraminiferal, calcareous nannoplankton for refining of biostratigraphy and paleoecology. The sediments of the well cores from the northern bays of Danube Basin (wells from the areas of Ratkovce, Trakovice, Špačince, Krupá and others) and Vienna Basin (mainly the Devínska Nová Ves, Devínska Kobyla, Malacky and Plavecký Štvrtok areas) are correlated based on the foraminiferal and nannoplankton events. In the present work we try to contribute into the debate on solving problem of Middle Miocene (Badenian/Sarmatian) biostratigraphy. The term Badenian was introduced and defined as a chronostratigraphic stage by Papp & Cicha in 1968 and was subdivided into three substages: Moravian, Wielician and Kosovian. The Sarmatian s. s. was stated as stage by Suess (1866) and in his original sense is used in the Central Paratethys. In the Eastern Paratethys the Sarmatian sl. is used as divided into the substages Volhynian, Bessarabian and Chersonian. Previous zonation of aforementioned stages based on benthic foraminifers proposed by Grill (1941, 1943) elaborated for the Vienna Basin still remained in use entirely for whole Central Paratethys; filled by local biozonations is the most widely used scheme today. The zonation consists of a vertical succession of benthic foraminiferal assemblages – based zones namely Lower and Upper Lagenidae, Spiroplectammina carinata and Bulimina-Bolivina, impoverished or Rotalia zones and was revised by Papp & Turnovsky (1953) for Badenian and Large Elphidia, Elphidium hauerinum and Porosonion granosum zones for Sarmatian. Subdivisions based on planktonic foraminifers were proposed by Cicha *et al.* (1975), but due to poorly represented planktonic organisms especially for shallow-water deposits is not always adopted. Nannoplankton zones NN4 – NN7 of Martini (1971) was adopted here firstly by Lehotayová (1982).

As main conclusion, the most useful leading events for biostratigraphical correlation seems to be from planktonic foraminifera FO of *Praeorbulina*, *Orbulina* associated with NN5 Zone, *Globigerina druryi*, *G. nepenthes* and levels with acme of globorotaliids (*Jenkinsella transsylvanica* and *Globoconella bykovaie*) associated with NN6 Zone. From the nannoplankton point of view we traced despite the NN4; NN5a,b,c and NN6 zones boundaries acme of the *Sphenolithus abies*, acme of *Discoaster* sp. div. and acme of *Reticulofenestra*, *Braarudosphaera* and *Calcidiscus* together with FO of *C. macintyreii*, theirs link to foraminiferal assemblages as well. One of the still raised problems for solving biostratigraphy of Lower/Middle Miocene stratigraphy is taxonomy of the foraminiferal leading species.

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MIOCENE PARATETHYAN DECAPOD CRUSTACEANS: DIVERSITY AND DISTRIBUTIONAL PATTERNS

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The Paratethys was a complex network of (mostly) shallow water marine basins which formed in the Oligocene as a result of the Alpine orogeny triggered with the collision of the African continent with the European plate. Paratethys as a network of inland seas was intermittently connected to the Mediterranean, North Sea basins as well as to the Indo-Pacific (Rögl 1998; Popov et al. 2004; Harzhauser & Piller 2007). During the Miocene, distinct biogeographical differentiation of the circum-Mediterranean area has been documented (e.g. Harzhauser et al. 2002, 2003, 2007 and references therein).

Recently, a database of the Miocene decapod crustacean occurrences from the Western and Central Paratethys has been compiled allowing detailed analysis of diversity and distributional patterns of these animals within the studied temporal and spatial scale.

From the Early Miocene, relatively well known are decapod associations of the Ottnangian (Hyžný et al. in press) and Karpatian stages (Müller 1998; Hyžný & Schlögl 2011), with 10 and 22 reported species, respectively. These assemblages are typically preserved in clayey sediments and at least the fauna from the Karpatian of the northern Vienna Basin is rather deep-water (below 200 m) (Hyžný & Schlögl 2011; Schlögl et al. 2011).

From the Middle Miocene (Badenian) of Central Paratethys, two major facies with decapod crustaceans are known: sand-free calcareous clays („Tegel facies”) dominated by a crab *Tasadia carniolica* (Bittner, 1884) and carbonates containing rich coral-associated faunas. In this respect, one of the best examples of the Badenian coral patch-reefs inhabited by decapods is the Fenk quarry in the south-eastern Vienna Basin (Bachmayer & Tollmann 1953; Müller 1984; Riegl & Piller 2000). In general, Paratethyan decapod associations were most diverse during the Badenian (Müller 1984), partly owing to the presence of reefal environments in the studied area. 74 decapod species are known from the Early Badenian, 57 from the Middle Badenian and 88 from the Late Badenian. Most taxa were described from the Great Hungarian, Vienna and Styrian basins.

At the Badenian/Sarmatian boundary the fossil composition changed abruptly and stenohaline groups disappeared (Harzhauser & Piller 2007). In the Sarmatian the open oceanic connections ceased and the entire Paratethys was inhabited by homogeneous euryhaline biota, most of which were endemic to the region (Rögl 1998; Popov et al. 2004). Such an endemite was probably also *Mioplax socialis* Bittner, 1884, a crab reported solely from the Lower Sarmatian strata (Bittner 1884; Glaessner 1928; Hyžný & Ledvák 2014). The Sarmatian decapod faunas were strongly impoverished; only 9 taxa were recorded in the Central Paratethys, which is slightly more than 10% of the decapod diversity in the Late Badenian.

The Upper Miocene deposits documented the existence of a large, long-lived brackish to freshwater Lake Pannon (Magyar et al. 1999). From these deposits fossil burrow systems attributed to callianassid ghost shrimps were reported (Hyžný et al. 2015). Freshwater strata sometimes contain remains of freshwater potamid crabs (Klaus & Gross 2010).

The Middle Miocene Mediterranean and Paratethys decapod assemblages as taken together were relatively homogeneous (at least at the genus level), although distinct when considering increasing rate of endemites in the Paratethys during the Miocene.

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STABLE ISOTOPE ECOLOGY OF HIPPARION FROM THE LATE MIOCENE PANNONIAN BASIN

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The horse *Hipparion* rapidly spread through Europe in the Late Miocene. Skeletal and stable isotope evidence from the earliest immigrant species suggest opportunistic feeding behavior, which make *Hipparion* a good proxy for changing vegetation. Despite a continuous sedimentary record through the Late Miocene and a lake system that has been the subject of extensive study, the Pannonian Basin lacks a well-documented geochemical record for the terrestrial environment. We use *Hipparion* to construct such a record and investigate ecosystem change.

Stable carbon and oxygen isotope records from *Hipparion* tooth enamel were used to reconstruct feeding habitat and drinking water for specimens from 23 localities in the Pannonian Basin. Carbon isotope values indicate that these localities offered a variety of habitats for *Hipparion* even as regional climate dried and cooled. Oxygen isotope values suggest that the water sources utilized by *Hipparion* ranged from standing ponds and local streams (replenished by precipitation and subject to evaporation) to extrabasinal rivers originating at high elevation. Based on these results, the Pannonian Basin seems to have been insulated from the drying and opening of ecosystems observed Central Europe through the Late Miocene. Furthermore, the composition of surface waters can offer insights into the mechanisms behind changing hydrology in the basin.

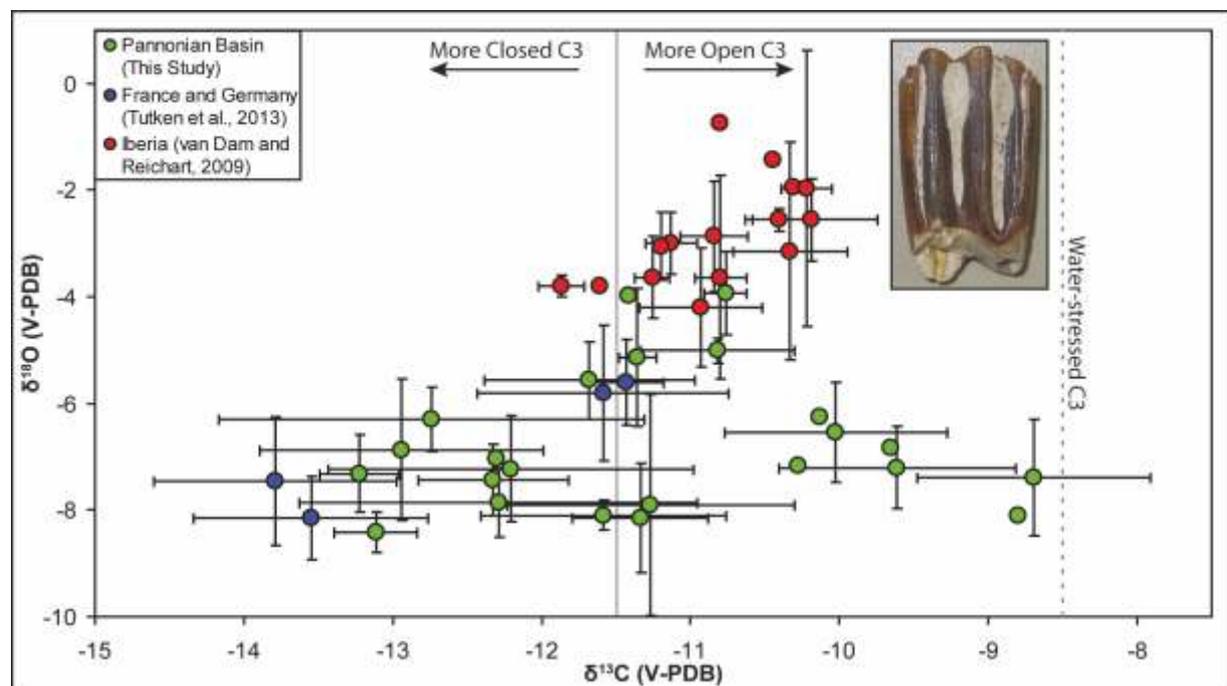


Fig. 1.: Mean stable carbon and oxygen isotope values of *Hipparion* tooth enamel (inset) from localities in the Pannonian Basin (green circles), France and Germany (blue circles; Tütken et al., 2013), and the Iberian Peninsula (red circles; van Dam and Reichart, 2009)

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REVISION OF LAKE PANNON *PYRGULA* SPECIES FROM NORTHERN TRANS-DANUBIA, HUNGARY

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Fossils representing the hydrobiid gastropod genus *Pyrgula Cristofori* & Jan, 1832, occur in the brackish to freshwater deposits of Lake Pannon (Upper Miocene). The first Pannonian *Pyrgula* species were described by Fuchs (1870a) from Radmanest, and these were followed by additional species introduced by, among others, Lőrenthey (1894), Brusina (1902), and Bartha (1956). The revision of these taxa is necessary because erroneous conclusions were drawn on the basis of the incomplete morphological descriptions and mistaken drawings.

Our material came from 22 outcrops in northern Transdanubia (NW Hungary) and mostly included specimens from museum collections and private collections. Here we discuss the various species in order of their geographical distribution from north to south.

Pyrgula(?) sergii Brusina, 1902, was first depicted from Kup, and it is also known to occur in Sopron, Lázi, and Hegymagas. The generic assignment of this species is still uncertain, because it is very similar to *Micromelania loczyi* Lőrenthey, 1894, described from Kurd. Although the type specimens of Brusina are well-preserved, we need more specimens to decide this issue.

Pyrgula archimedis Fuchs, 1870a, is a small species. Its seven-whorl shell is 4.4 mm long and 2 mm wide. The shell has 3 longitudinal keels, but these are all visible only in the body whorl; the second and third whorls display 1, whereas the fourth to sixth whorls show 2 keels only, because the other keels are covered by the following whorl. The shell lacks additional ornaments. This form occurs in northern Transdanubia in a single locality, Dáka, and these specimens fully correspond to the type specimen described from Radmanest.

The most common *Pyrgula* species in the investigated area is *Pyrgula incisa incisa* Fuchs, 1870a. This species is abundant in the outcrops surrounding the Bakony Mts. Although Fuchs (1870b) observed that specimens of this species from Tihany are smaller than those from the type locality, Radmanest, he attributed this difference to intraspecific variability, and we share his opinion. Our specimens from Kötcse, however, fully correspond to the Radmanest specimens. A slightly wider specimen from Tab was described by Bartha (1956) as *Pyrgula obesa*, but we think that it is but a variety of *Pyrgula incisa*. The localities of *P. incisa* include Balatonfüzfő, Papvászár-hegy and János-hegy; Csór, cut of road No. 8 and waste deposit site; Dáka; ?Doba; Öcs; Tihany, Fehérpart and Gödrös.

A variety of *P. incisa* is the subspecies *P. incisa mathildaeformis* Fuchs, 1870a. Apart from its Radmanest type locality, this form occurs in Tihany, Gödrös; Balatonfüzfő, Papvászár-hegy; Balatonalmádi; and Várpalota, Kikeri-tó. In overall shape and size it corresponds to the nominal subspecies, but it has strong ornaments: slight nodes and even spines form where the longitudinal keels cross the transverse elements of ornamentation („thickened growth lines”). The stratigraphic range of this form is confined to the *Lymnocardium decorum* and *Congerina praerhomboidea* zones.

The next species is *Pyrgula unicarinata* Brusina, 1902; it occurs in the outcrops of the Balaton highland, such as Tihany, Balatonalmádi, and Balatonfüzfő. Only a few specimens are known, and all are similar to the type material. Brusina depicted this species from Kindrovo, but he did not give description of its morphology. Based on the adult specimens from the Balaton highland, an 8-whorl specimen is 7.2 mm high and 3 mm wide. The whorl is convex below the keel, but concave above it. Growth lines are well visible in the concave part, whereas longitudinal lirae can be observed below the keel. The stratigraphic range of the species is limited to the *Lymnocardium decorum* and *Congerina praerhomboidea* zones.

Comparing specimens from our Balaton highland collections with type materials, we came to the conclusion that *Pyrgula bicarinata* Brusina, 1902 and *Pyrgula incisa pannonica* Lőrenthey, 1905, are synonyms of *Pyrgula angulata* Fuchs, 1870a. Fuchs' type specimen from Radmanest is a juvenile individual having 6 whorls only. On this relatively poorly preserved specimen, the second longitudinal keel characteristic of this species can hardly be observed. The appearance of this second keel immediately above the suture depended on ontogenetic evolution and/or on environmental effects. Another characteristics of the species is the presence of longitudinal lirae on the shell. The development of this ornament can vary: the lirae can be sharp or blunt. This species occurs in Tihany, Fehérpart; Balatonalmádi; Balatonfüzfő, Papvásár-hegy; Balatonkenese; Csór; Balatonkeresztúr; and Fonyód. It is confined to the *Lymnocardium decorum* zone.

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POLYMETALLIC MINERALISATIONS RELATED TO THE MIOCENE BASINS IN NORTH ALGERIA

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In the Maghrebide Belt of North Algeria, strabound and vein Pb, Zn, Cu, Sb, Ba, F mineralization are located in many districts as: Berrouaghia (Bibans) Hammam N'Bails and Boukdema (neretic plate form) M'Sila and Dj. Boutaleb (Hodna), Aïn Mimoun (Khenchla), Lakhdaria and Keddara (Internal Zones) and Ouenza (Saharian Atlas)

The mineralizations are mostly linked to Miocene and Mio-Pliocene sediments and /or associated with structural Miocene events.

In the northern part of the Maghrebide Belt, these mineralizations are characterized by the appearance of Cu, Ba, F and Sb.

Some of the galena mineralization occurs with paleochannels in the lower part of the Miocene formations whereas the vein type mineralization occurs as infilling normal faults cross-cutting the terrains from Cretaceous to Mio-Pliocene age. Ba, F mineralization is occasionally linked with an Oligocene-Miocene conglomerate.

Fluid inclusions were studied in fluorite, barite and calcite from some vein deposits located in Eastern Saharian Atlas (Ouenza, Mesloua and Hameimat) and in the Internal Zones (Keddara and Lakhdaria massifs).

These fluid inclusion data indicate salinities ranging from low to very high (from 0.2 to 25 % eq. NaCl) and a bulk homogenisation temperatures (Th) on liquid phase, are ranging from 70-100°C to 160°-180°C.

This fluid inclusion suggests a variation in temperature of formation between stages of mineralization and the large variation of salinity of the fluid reflects a temporal and spatial evolution. Thus demonstrate an apparent constancy of the fluid source all along the late Miocene-Pliocene in the northern part of Algeria.

Both geological and microthermometric data on these mineralizations show the role of the low temperature basinal brines related to the geodynamic events. These basins are submitted to the distensive and compressive stages of the late alpine tectonic. In that respect, these mineralizations could related to the class of MVT.

PLIOCENE MAMMALS OF THE PULA MAAR (HUNGARY)

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The first important vertebrate remains from the alginite deposited in a Pliocene crater lake near the village of Pula (Németh et al. 2008) were discovered in 1986, some 13 years after the exploitation of the alginite had started (Futó 1988; Kordos et al. 2013). This locality was introduced to the international scientific community in 1988 with the extraordinary discovery of the first complete skeleton of a rhinoceros, nowadays on display in the Bakony Museum of Hungarian Natural History Museum in Zirc. Four other rhinoceroses, complete and fragmentary skeletons of both juvenile and adult specimens, were excavated between 2000 and 2010. Of these five individuals, four were found in the so-called 'alginite' levels (Németh et al. 2008) dated around 4.2 Ma. The fifth one was found in a poor preservation state, in a layer of freshwater limestone.

Primarily attributed to *Stephanorhinus megarhinus*, the rhinoceros of Pula raises numerous paleontological and taxonomical questions on the fossil species of rhinoceroses in the European Pliocene. Recently, the species *megarhinus* was included in the genus *Dihoplus* (Heissig, 1999; Lacombat and Mörs, 2008), but here the specific attribution is questioned. The '*megarhinus*' rhinoceros is a large rhino without any bony nasal septum, whereas this septum is visible in the CT picture of the Pula specimen (Kordos et al. 2013). In addition, the European Pliocene sediments have yielded many rhinos attributed to *megarhinus* and showing a rather small size and/or a partially bony nasal septum. Specimens from Pula and Gödöllő in Hungary (Mottl, 1939), Roatto and Dusino in Italy (Campanino et al., 1994), and Perpignan in France (Guérin, 1980) are all attributed either to a typical *S. megarhinus*, or to a smaller-sized *S. megarhinus*, or to *S. jeanvireti*. In fact, our material may justify the introduction of a third species; this idea will be confirmed or discarded by the paleontological research project of Pula. The studies of historical and recently discovered fossil collections will allow us to propose a new paleontological approach and phylogenetic relationship for these rhinoceroses of this time slice, relatively poor in fossil remains.

The associated fauna, found in earlier surveys, is also under investigation. It includes two large bovids: Bovidae gen. ind. sp. ind. and *Pliodorcas* nov. sp. (Lacombat et al. in progress). For this study we re-analyze the mammal remains from another locality, Gödöllő, lying about 200 km NE of Pula, because they are of about the same age, and contain the same rhinoceros as Pula, plus a small cervid (cf. *Cervocerus*), a suid (*Propotamochoerus provincialis*), *Hipparion crassum*, *Anancus arvernensis* and *Tapirus hungaricus* (Mottl, 1939). We will compare the two localities and put them in a broader Eurasian framework of mammal evolution, migration, and environmental change.

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BENTHIC FORAMINIFERA FROM THE TETHYAN AND PARATHETHYAN REGIONS: TAXONOMIC BIAS IN THE RECONSTRUCTION OF PALEOENVIRONMENTS

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Benthic foraminifera assemblage composition is an important tool in the reconstruction of marine paleoenvironments. In the study of the Miocene development of the Tethyan and Paratethyan regions, and of episodes of connectivity between the marine basins, benthic foraminifera can be used rather efficiently. However, the data derived from these assemblages might be more useful if it were possible to line up taxonomical concepts used by workers in the two regions.

Although differences exist in the taxonomic composition of Tethyan and Paratethyan benthic foraminiferal assemblages, these regions also have many taxa in common. There are cases, where the same species are known by different names in the different regions; e.g., *Bulimina* vs. *Baggina* for the same genus. Taxonomic comparison of benthic assemblages from both regions is also complicated by differing species concepts used by different scientific groups. Differences also exist in the methodologies of data acquisition and evaluation.

As we consider taxonomic concepts the first problem to tackle, our aim is to document the species concepts used in both study areas by collecting SEM pictures and taxonomy lists, and by comparing the existing nomenclatures. This way we hope to track similarities and differences in assemblage compositions between the regions in more detail, in order to facilitate the exchange of information between workers in the Tethyan and Paratethyan regions.

CENOZOIC SEDIMENTARY RECORD AT THE CENTRAL WESTERN CARPATHIAN AND NORTHERN PANNONIAN DOMAINS JUNCTION: INTERPRETATION OF A COMPLEX GEODYNAMIC EVOLUTION

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Cenozoic geodynamics of the Central Western Carpathians and Northern Pannonian domain junction is reflected in opening and disintegration of different types of basins, which Palaeogene and Neogene sedimentary fill is superimposed one above the other. (1) The Hungarian Paleogene Basin development mirrors intricate processes induced by the growing push of Adriatic plate in hinterland of the Eastern Alpine – Western Carpathian orogenic system, leading to individualization of the ALCAPA microplate at the Oligocene–Miocene boundary. This process was preceded by amalgamation of both terranes (Central Western Carpathian and Northern Pannonian domain) along the Hurbanovo – Diösjenő lineament (HDL), considered as eastern prolongation of the Periadriatic lineament in the Palaeocene–Eocene. The Eocene sedimentary fill of the **Hungarian Palaeogene Basin** is cut by this lineament, and its deposits are present only on the Transdanubian Range units. The measured tectonic activity of HDL was documented as a dextral shear during this time. The fault system is covered/sealed first by the late Rupelian sediments of the Kiscell – Číž Formation in its north-eastern segment (Rapovce fault), where the **Pétermásara Basin** opened. Moreover, the extensive erosion of the western part of the Hungarian Palaeogene Basin together with the Danube Basin basement brings about the Oligocene uplift of the area at the junction of Alpine, Carpathian and Pannonian domains. (2) The Late Oligocene–Early Miocene development of the Pétermásara Basin was accompanied with tectonic escape of the microplate. Shift of its depocentres toward the East took place during the Egerian, and the basin was full-filled in the Eggenburgian–Ottangian time. (3) The Middle Miocene rifting of the present **Danube Basin** begun after soft docking of the ALCAPA western part in the European platform embayment in the North. Basin opening coupled with extension of the microplate rear part and associated with uplift of the asthenospheric mantle during the synrift stage of the Pannonian Basin System evolution. The Badenian and Sarmatian subsidence associated with sedimentation in marine environment. The tectonic activity of HDL was documented as a sinistral shear during this time. (4) The opening of Late Miocene depocentres of the whole Pannonian Basin System was partly affected by pull of subduction in front of the Eastern Carpathians. Sedimentary record of the Danube Basin documents its gradual filling up with succession representing sedimentation in the **Lake Pannon** basin floor, shelf slope, deltaic and finally in alluvial plain environments.

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THE LATE MIOCENE TO THE PLEISTOCENE EVOLUTION OF MEDVEDNICA MT. (SW PANNONIAN BASIN SYSTEM, CROATIA): THE ROLE OF SEDIMENT SOURCE

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Medvednica Mt. is situated in the south-western part of the Pannonian basin system (PBS); a depositional area located between the mountain chains of the Alps, the Carpathians and the Dinarides. During the Middle Miocene the Pannonian basin existed as a part of the marine Central Paratethys, in the Late Miocene it was covered by the brackish Lake Pannon, while during post-Miocene time it was a mainland dissected by a branched river network, floodplains and small freshwater lakes (Kovačić, 2004; Piller et al., 2007).

The PBS consists of several deep basins separated by uplifted blocks. The thickness of the Upper Miocene, the Pliocene and the Quaternary deposits in the deep basins in the SW part of the PBS exceeds 5000 m, while on the uplifted blocks it is less than 1000 m (Saftić et al., 2003). The Medvednica Mt. represents an uplifted block which separates the Zagorje Basin in the NW from the Sava basin in the SE.

Due to tectonic activities from the Middle Miocene to the Quaternary (Tomljenović & Csontos, 2001), and lake level oscillations during the Late Miocene, Medvednica Mt. had a changing role as a source of clastic material. At the beginning of the Late Miocene some parts of Medvednica were above the lake water level and acted as a source of clastic material. The material disconformably covered Middle Miocene or/and older rocks, but more often it was transported to the lake and deposited together with shallow-water limestones or deep-water marls. During the middle Late Miocene, as a consequence of a water level rise in Lake Pannon, Medvednica was completely flooded and ceased to exist as a source of clastic detritus. Until the end of the Miocene it formed an underwater hill that separated the Zagorje basin from the Sava basin. The next depositional phase started on the northern slopes of Medvednica at the end of the deposition of Banatica beds, while on the southern slopes it started during the deposition of Abichi beds. Mineralogically and structurally mature sandy to silty material derived from the Alps by prograding deltaic systems was supplied to Lake Pannon causing its shallowing and narrowing. The deposition began in a prodelta environment which was, by the end of the Miocene, gradually replaced by a delta front environment. During the Early Pliocene Medvednica was covered by floodplains with an extensive river network, small lakes and swamps. The clastic material still originated from the Alps (Kovačić, 2004). The new compressional phase in the evolution of the PBS which started at the end of the Miocene and intensified in the Quaternary (Tomljenović & Csontos, 2001) caused strong uplifting of Medvednica. During the Pleistocene Medvednica was a mountain and again became an important source producing a huge amount of clastic material.

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FOSSIL INSECTS FROM THE PLIOCENE ALGINITE OF PULA, HUNGARY

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Fossils of insects are relatively rare in Hungary; the most diverse insect fauna was published from the Sarmatian (Middle Miocene) sedimentary rocks from Tállya, northeastern Hungary. This fauna represented 8 orders, and the fossils could be determined at the family level (Sziráki & Dulai 2002).

The alginite mine at Pula, western Hungary, Balaton highland, is the second largest in the country. Alginite was deposited here in a 4.1 million year old crater lake, and has been exploited for more than 40 years. Fossils recovered from the alginite mine include leaves, mosses, bones of fishes, rhinos, antilopes, pigs and dears, and, as a result of systematic collecting campaigns and skilled preparations of the last 5 years, exceptionally well-preserved insects.

Occurrence of fossil arthropods in the deposits of Pliocene crater lakes of Pula and Gérce was first reported in 1997. A form belonging to subclass Acarina and representatives of 6 other insect orders were published. The well-preserved fossils were identified to the genus level. The material from Pula included the first fossil representatives of orders Psocoptera and Trichoptera in Hungary (Krzeminski et al. 1997).

With the systematic collecting we have been conducted since 2010, we found representatives of 9 insect orders, including the first fossil specimens of order Sternorrhyncha and those of subclass Araneae (spiders) in Hungary (Tóth et al. 2013, Katona et al. 2014).

Most of the well-preserved specimens were determined at genus level, some were even compared to living species. Land forms prevail in the material, the most diverse group being order Coleoptera (beetles) with 20 taxa representing 13 families.

Two of the identified taxa are not living in Hungary today; they inhabit the Mediterranean region. One of them belongs to order Isoptera (termites), the other to the genus *Di cladispa* (family Chrysomelidae, leaf beetles; Tóth et al. 2013).

Dragonfly nymphs (Odonata) and aquatic true flies (Diptera) are represented in the Pula fauna with many individuals and species. Four species of dragonflies have been identified so far (some of them with some uncertainty): *Lestes barbarus* (Fabricius, 1798), *Cordulia aenea* (Linnaeus, 1758), *Sympetrum sanguineum* (O. F. Müller, 1764), and *Sympetrum vulgatum* (Linnaeus, 1758) (Tóth et al. 2013).

The only but abundant representative of mayflies (Ephemeroptera) in the fauna is probably identical with the recent species *Cloeon dipterum* (Linnaeus, 1761) (Tóth et al. 2013).

The true flies (Diptera) are represented first of all by pupae of various nonbiting midges (*Ablabesmyia*, *Micropsectra*, *Procladius*) and imagos of non-identified species. Land forms include a hoverfly (*Syrphidae*) imago, identified as *Platycheirus angustatus* (Zetterstedt, 1843) (Tóth et al. 2013).

We also found many water boatmen (*Corixidae*), identified as *Sigara limitata* (Fieber, 1848). *Micronecta griseola* Horváth, 1899, belonging to the family *Micronectidae*, and *Nepa cinerea* Linnaeus, 1758, a water scorpion were also recognized in the material.

In summary, collecting and preparation activity in the last 5 years has revealed the presence of 46 arthropod taxa in the Pula alginite. They represent the following groups: Araneae (spiders): 3 taxa, Ephemeroptera (mayflies): 1 taxon, Odonata (dragonflies): 4 taxa, Isoptera (termites): 1 taxon, Orthoptera (grasshoppers and crickets): 1 taxon, Heteroptera (true bugs): 6 taxa, Sternorrhyncha (plant lice): 1 taxon, Coleoptera (beetles): 20 taxa, Hymenoptera (sawflies, wasps, bees, ants): 5 taxa, and Diptera (true flies): 4 taxa.

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DATING OF CENTRAL PARATETHYAN DEPOSITS WITH SIS (SR-ISOTOPE STRATIGRAPHY)

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Correlation of Central Paratethyan (CPT) Oligocene to mid-Miocene regional stages with the geological time-scale is often difficult because of the strong endemism of fossils lived in the inland sea of that time. Here we try to overcome this problem by mean of Sr isotope stratigraphy performed on well preserved low Mg biotic calcite of bivalve shells (mainly *Pecten* and *Ostrea*) collected from key locations of the former Central Paratethys in Hungary, Austria, Romania and Slovakia. All samples before SIS analysis were carefully screened for diagenesis and shell preservation has been evaluated using a rigid petrographic (SEM and optical microscopy) and geochemical approach. Results listed below are the first data from a larger forthcoming set.

The age of all four samples taken from the basal and lower part of the Egerian (Novaj, Nyárjastető; Eger, Wind brickyard; Miskolc, Csókás; Budikovany – SK) appeared to be between 24.5 and 23.0 Ma corresponding to the late and terminal Chattian. These data are at least 3 Ma younger than expected and necessitate repositioning of the Kiscellian/Egerian boundary. The Bretka (SK) samples taken from the upper, Miocene part of the Egerian mark 22.4–21.9 Ma (early Aquitanian) as expected.

Of the localities believed traditionally Eggenburgian the Sr-isotope age (23.0–22.3 Ma) of Budafok Sand from Bercel can be treated with care and should be checked because of the high Fe-content of the sample. The age of the Darnó Conglomerate from Szajla, Kis-hegy appeared to be between 21.4 and 20.9 Ma corresponding both to late Aquitanian in accord with the newly found *Miogypsina tani* and to basal Eggenburgian in the CPT subdivision. The Coruşu (RO) sample with large pectinids marks 19.9–19.2 Ma (early Burdigalian). Surprisingly young (18.5–17.9 Ma) age (corresponding to about the Eggenburgian/Ottnangian boundary) has been obtained from the type-locality of the Budafok Sand from Budapest, Pacsirta Hill. Samples from the upper part of the Pétervására (Fil'akovo) Sandstone from Parád, Ilona Valley and Lipovany (SK) gave even younger Sr-isotope ages (18.2–17.6 and 18.3–17.7 Ma, respectively), which correspond rather to the early Ottnangian. These data are, however, in accord with the Ottnangian character of mollusks and also with the revised (17.5–16.9 Ma) age of the overlying lower rhyolitic tuff from Ipolytarnóc (Pálfy et al. 2007).

In the case of the Várpalota, Bánta-puszta localities similar Sr-ages have been obtained from both sides of the locally assigned Ottnangian/Karpatian boundary (16.1–15.3 and 15.9–15.1 Ma, respectively) corresponding to the early Badenian and early Langhian. Similar (16.1–15.3 Ma) Sr-age came out from the Egyházasgerge Sand from Csernely thought to be Karpatian. The Sr-age (15.7–14.9 Ma) from the Szabó quarry in Várpalota believed to be early Badenian is not surprising in itself, however it is astonishing in comparison with the data from Bánta-puszta.

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THE ORAVA-NOWY TARG BASIN: TECTONIC ACTIVITY AT BASIN MARGINS VS. SEDIMENTARY RECORD

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The Orava-Nowy Targ Basin (ONTB) is an intramontane, tectonically originated depression filled with Middle Miocene-Quaternary deposits. It straddles the Central/Outer Carpathians border at which three units occur within the basin basement: Magura Nappe (MN), Pieniny Klippen Belt (PKB) and Central Carpathian Palaeogene Basin (CCPB). The infill of the basin constitutes the only Neogene sedimentary record in this region being an excellent subject for study some aspects of the structural evolution of underlying units. Such a study has been made by an interdisciplinary team last years.

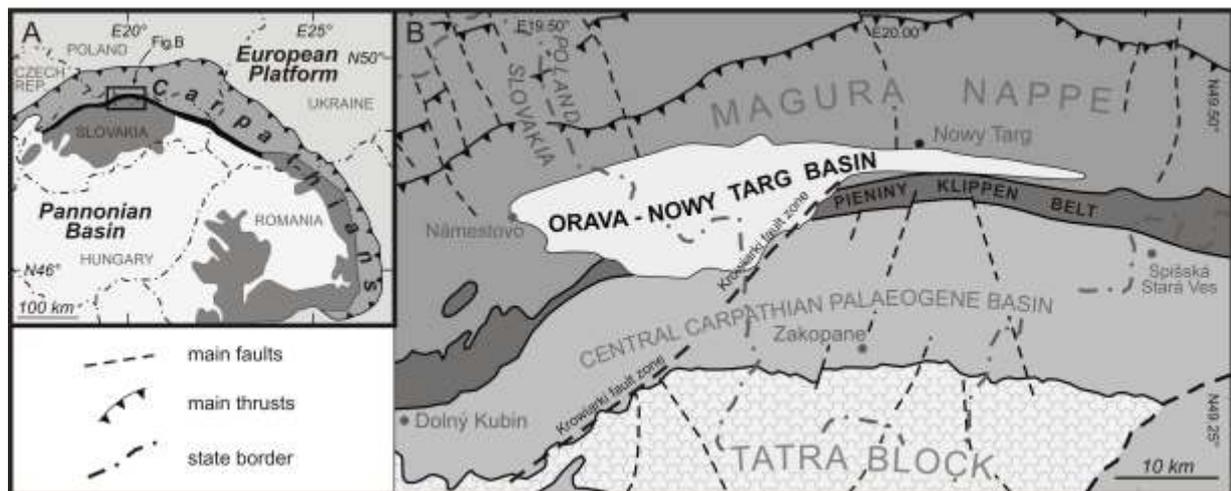


Fig. 1.: Schematic map of the Central Western Carpathians (A) and the study area (B) (after Lexa et al., 2000 and Łoziński et al., 2015, modified)

The structural analysis including fracture and fault analysis was done within the area of CCPB south of ONTB. The pattern revealed shows two main structural domains: eastern with significant contribution of deformations driven by compression, and western with remarkable occurrence of deformation that are extensional in character. They are separated by the Krowiarki fault zone (Bac-Moszaszwili, 1993; Baumgart-Kotarba, 1996, 2001; Baumgart-Kotarba et al., 2004) with high tectonical imprint of strike-slip faults, map-scale rotation of blocks around vertical axis and occurrence of mesofolds with vertical axes. This zone is interpreted as the northeasternmost segment of the Myjava lineament zone (Janků et al., 1984; Pospíšil et al., 1986) which starts in the Vienna Basin region and ends probably within MN. This zone coincides with the eastern border of the Orava part of ONTB and probably was involved in the basin development. The structural pattern of underlying CCPB points to the strike-slip, sinistral character of the fault zone resulting at the fault tip-zone in forming of depression west of the structure.

The activity of this fault zone can be traced within Neogene sedimentary record of the ONTB. The basin deposits are represented mainly by siltstones with sandstone intercalations, clayey siltstones and claystones with thin brown coal seams (Watycha, 1976). They were deposited in river environments including floodplain and channel sedimentation as well as lake and swamp environments (Łoziński et al., 2015). Conglomerates occur only in some parts of the basin and were deposited in small river channels or within alluvial fans. The material was derived mainly from surrounding areas where MN, PKB, and CCPB were exposed. The conglomerates distribution and large quantities of fine-grained deposits of the basin infill suggest that weathering

process was intensive and led to quick clast disintegration. The sedimentary study has revealed that the area of ONTB close to the Krowiarki fault zone is especially abundant in alluvial fans sediments represented by several meters thick conglomerates and sandstones. They indicate the Miocene palaeorelief contrast between mountainous area east of the fault zone and flat depression west of the zone. This means that the present east border of the ONTB is coherent with the Miocene border of the depression and suggests Neogene-Quaternary activity of the fault zone.

The Neogene alluvial fan facies association related to palaeorelief contrast can be also found at the northern margin of the basin (Tokarski et al., 2012) but it does not exist (except Quaternary deposits) at the present-day southern margin (Łoziński et al., 2015). This suggests that the Neogene depression spread more to the south. The basin infill was partially subjected to uplift and erosion (Tokarski et al., 2012, Łoziński et al., 2015) what was probably related to the major change of character of Krowiarki fault zone activity.

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COMBINED (U-TH)/HE AND U-PB ZIRCON DATING TO CONSTRAIN THE ERUPTION EVENTS OF THE EARLY TO MIDDLE MIOCENE IGNIMBRITE FLARE-UP IN THE PANNONIAN BASIN, EASTERN-CENTRAL EUROPE

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In the Carpathian-Pannonian region, an ignimbrite flare-up episode occurred during the Miocene. The timespan of the volcanism has been considered to be about 7 Myr, between ~21 Ma and 13.5 Ma (Szabó et al, 1992; Márton and Pécskay, 1998; Pécskay et al., 2006). This volcanism was fed by large volume dacitic to rhyolitic magmas producing pyroclastic rocks (mainly ignimbrites and fall-out tuffs), and was coeval with the formation of the Pannonian basin by major lithospheric stretching (Horváth et al., 2006). Most of these volcanic rocks are, however, covered by younger sediments due to the major subsidence during the post-rift period (since Late Miocene). Borehole data indicate that the thickness of the Miocene pyroclastic suites could be several hundred meters and in certain areas exceeds the 1000 meter. Pyroclastic deposits form important key horizons often extending over several 10's kilometre and thus have stratigraphic significance.

Previously, the eruption ages of the silicic volcanism were determined by K/Ar radiometric dating, stratigraphic considerations, and fossil contents of the associated sediments. Palaeomagnetic rotation data added further constrains on the age of the volcanic formations, since two major block-rotation events were identified in this area contemporaneously with the silicic volcanism (Márton and Fodor, 1995; Márton and Pécskay, 1998). Thus, conventional view of the Miocene stratigraphy includes definition of three main regionally extended volcanic units (ages of 21.0-18.5 Ma; 17.5-16.0 Ma; 14.5-13.5 Ma, respectively). However, the precision ($\pm 1-2$ Ma) of the determined K/Ar ages does not allow clear separation of these units and a rigorous evaluation of the temporal evolution of the volcanism. Furthermore, geochemistry-based correlation studies suggested more complex eruption scenario (e.g., Harangi et al, 2005; Lukács et al. 2007; 2010).

Thus, we conducted a high-precision zircon dating to constrain better the eruption ages that could help also to have a better understanding on the nature of this significant silicic ignimbrite flare-up event. The Bükkalja Volcanic Field (BVF; Northern Hungary) provides the exceptionally good opportunity to perform this study, since there are well-preserved outcrops and the pyroclastic products are regarded to cover almost the whole timescale of the volcanism. We used integrated high-precision in-situ zircon U-Pb dating by LA-ICP-MS and (U-Th)/He dating on a range of volcanic rocks. The U-Pb ages indicates the crystallization ages, whereas the latter one can be used to constrain the eruption dates. We collected samples from continuous stratigraphic sections in outcrops and boreholes in order to get a fine-scale determination of eruption frequency. One of the three boreholes is located as far as ~20km to the south of the BVF, at the southern margin of the Vatta-Maklár Trough. Thus, we could carry out also a regional correlation of the volcanic units. The samples represent both pyroclastic flow and fall deposits.

The in-situ zircon U-Pb data show usually wide age spread within individual samples suggesting prolonged zircon crystallization. Eruption ages are approached by the weighted mean average values in case where zircons showed homogeneous age distribution and by the mean age of the youngest age populations, where of zircons showed heterogeneous age distribution. These statistically defined ages are regarded being the closest to the eruption ages, but are not necessarily equal with them.

The (U-Th)/He age data are in very good agreement with the determined eruption ages based on the U-Pb zircon data. This indicates that these silicic volcanic formations were not

covered by thick sedimentary deposits. Our new results suggest that the volcanism could occur for a shorter time than previously thought, from 18.2 Ma to 14.0 Ma and confined primarily to the major lithospheric extension period of the Pannonian Basin. We could distinguish at least six major active volcanic periods. Remarkably, the new ages determined by zircon dating differ significantly from the previous K/Ar ages, the difference is up to 4 Ma. Many samples previously regarded to belong to the oldest volcanic unit have been revised and it turned out that majority of the volcanic rocks formed during a short volcanic phase at about 16-17 Ma. There were short repose time between the active phases, except for one cases when 1 Ma long lull of volcanism appears to have occurred between ~16.2 Ma and 14.8 Ma. The volcanic deposits of the stratigraphic sections from boreholes and outcrops can be well correlated based on the U-Pb age data that helps also to define particularly large eruption events.

The new in-situ zircon dating enable an insight into the formation of the magma reservoirs and constrain the timescale of zircon crystallization and recycling. Most of the eruption event was preceded by prolonged (often over 1 Ma) development of the silicic magmatic system. The new suggested eruption ages characterize the silicic volcanism and magma evolution with a much better precision and resolution (i.e. errors are ~200-300 k years) and it sheds new light concerning the nature and the volume of the volcanic activity.

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MICROPALAEONTOLOGICAL STUDY OF THE MIDDLE MIOCENE EXPOSURE AT THE PATA MEADOW, TRANSYLVANIAN BASIN, ROMANIA

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The Miocene paleogeographic reconstruction of the Paratethyan area is a difficult task due to the rapid shifts in paleobiogeographical conditions, intense volcanic activity and tectonics.

These rapid changes are best reflected by the Transylvanian Basin (TB) through the evolution of the Miocene depositional environments e.g. after the deposition of the Middle Badenian evaporites in the basin, Late Badenian (Kosovian) deep marine sedimentation occurred. The deposited dysoxic-type shales and pelagic marls diatoms, radiolarians, silicoflagellates, and planktonic foraminiferal assemblages (*Velapertina* Biozone) and pteropods are abundant (Krézsek & Filipescu, 2005). The occurrence of agglutinated benthic *Bogdanowiczia pocutica* Pishvanova was related to the sandstones of highstand systems tracts, and represents a change in the deep-marine environment (Filipescu, 2004a), whilst the initiation of the transgression at the end of the Badenian was related to a planktonic invasion (Filipescu & Silye, 2008). This transgression prevailed until the base of the Sarmatian, and resulted in the acme of *Anomalinoidea dividens* Łuczowska, which is considered a regional index taxon of the Paratethyan biostratigraphy (Filipescu, 2004b). Nevertheless, due to the lack a proper outcrop, the Badenian/Sarmatian transition cannot be studied in full detail in the Transylvanian Basin.

This study presents the micropaleontological investigation of the samples recovered from a newly discovered outcrop in the western part of the TB (close to Cluj-Napoca). The sampled Middle Miocene marls were deposited in deep-marine environment. The collected samples were processed by standard micropaleontological methods i.e. dried and weighed, 300 g of each was washed on a 63 µm sieve to remove the clay content. The micropaleontological analysis was performed with the aid of a stereomicroscope and a scanning electron microscope. The taxonomical classification of specimens is based on adequate literature. Besides the planktonic and benthic foraminifera in the sand-sized residue ostracods and pteropods were also found. The dominance of planktonic *Velapertina indigena* Łuczowska with other associated foraminifera in most part of the studied outcrop, clearly indicate Late Badenian age for the studied strata, and suggest a dysoxic, deep marine depositional environment.

However in samples collected in the upper part of the studied exposure the presence of a few *Anomalinoidea dividens* was observed. This would be a clue for the Sarmatian age of the upper part of the outcrop. Interestingly in none of the samples small tenuitellinids occurred. Our further studies are focused on the detailed investigation of this important stratigraphical transition, which may offer new information about the micropalaeontologic and environmental changes at the Badenian/Sarmatian transition in the Paratethyan area.

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STYLES OF DEPOSITION IN THE NEOGENE BASINS OF HUNGARY

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The deposition of the Neogene formations in Hungary is represented by a long-lasting, however non-continuous process. The deposition went on during at least four well-distinguishable phases differing from each-other in geographical position, in the localization of depocentres and in the intensity of sediment accumulation.

The style of a particular sediment deposition is the function of a number of simultaneous factors:

- *tectonic setting of the basin*

extent, size and geometry of the basin,

tectonic subsidence of the basin

height and morphology of the surrounding mainland delivering siliciclastic sediment input

- *geographic setting of the basin*

marine connections toward the world-seas

global eustatic sea-level fluctuations

fresh-water input influencing the salinity of water-bodies in the basin

- *patterns of hydraulic regime of river systems*

water input of the rivers (function of climate)

relief energy determining the sediment input

- *climatic factors*

influencing the forming of non-siliciclastic, autochthonous deposits as chemical and biogenic sediments

amount of calcareous bio-production

Late Egerian to Early Ottnangian

The early Early Miocene is represented in Hungary by the terminal phase of the Paleogene sedimentary cycle. The Buda-type Paleogene basin extended upon the Alcapa microplate and upon the heavily sheared and deformed Mid-Hungarian Megaunit along a NE-SW strike. The extent of the longitudinal basin did not cross the Mid-Hungarian and Raba lineaments. A marine seaway can be assumed toward the Carpathian foredeep in this time-interval. The Late Egerian-Eggenburgian basin is dominated by overwhelmingly marine siliciclastic deposits. From the Early Eggenburgian on, the central deep basin of the pelitic Szécsény Schlier started to get filled up. Sandstone bodies intruded from the East (Darnó zone), from the South (Balaton lineament) and from the West (Buda line) causing a shallowing up in the basin.

This process terminated in the total filling up of the Basin by the earliest Ottnangian. The depocenter of the Early Miocene basin might have been between the East-Cserhát Mts and the Ózd-Putnok area. The maximum sediment accumulation rate was cca. 45-50 m/my around Szécsény and 150-160 m/my at Putnok.

According to widely accepted models the Pannonian basin might have originated from a back-arc basin which underwent an intensive extension, synchronously with the forming of the thrust and fold belt of the Outer Carpathians. Anyhow, the Pannonian basin geometrically is not a symmetric, bowl-like depression, but it has several, shallower and also extremely deep sub-basins. While the general extension of the lower, ductile lithosphere of the Pannonian basin can be explained by plastic deformation and stretching, until the extension was manifested in brittle-style tectonics in the upper lithosphere (extension along low-angle normal faults, transform fault activity). The forming of the deep sub-basins always can be linked to one of these two processes.

Ottngian to Karpatian

By the beginning of the Ottngian two major basins developed in the internal parts of the Pannonian basin-system. In the North, a predominantly marine basin formed, its borders surprisingly fit to those of the late Buda-type Paleogene basin. The mid-Ottngian transgression reached the basin from the SW and deposited almost exclusively siliciclastics: the Salgótarján Coal-bearing Fm, and then marine beds, i.a. the basinal Garáb Schlier. The deposition center of this schlier migrated toward the North compared to the previous, Paleogene schlier. The accumulation rate of this sedimentary series is quite high, cca. 300 m/my. The late Early Miocene marine deposits are interfingering with thinner continental beds toward the Transdanubian Central range.

Another new basin opened in the Early Ottngian in S-Transdanubia: the Mecsek Neogene basin. Its strike is also NE-SW and it extends toward the Danube-Tisza interflow and to the northern segment of the Drava basin. The basin accumulated a thick series of continental siliciclastic deposits ranging from torrent-river conglomerates to fine-grained, pelitic floodplain, lake and lagoon deposits (Szászvár Fm). These deposits suggest a near elevated dryland as source-area. The deposition of this series continued also in the earliest Badenian. The depocenter might have occurred NE from the Mecsek Mts. The maximum depositional rate is close to 400 m/my.

Badenian to Sarmatian

The Early Badenian is the time of intensive subsidence in the intra-Carpathian area. Although the deposition continued in the former basin, in North Hungary, but the sediment accumulation slowed down and terminated by the end of Sarmatian. In the Mecsek basin the deposition of sediments continued in a deeper, marine environment. In addition to these, a number of new sub-basins opened, as the Little Hungarian Plain, Dráva basin, Jászság, Derecske and Békés depressions.

The Neogene sequence of these new sub-basins starts with a set of continental siliciclastic beds ranging from a few dozens of metres to 400 m. The marine transgression reached these sub-basins only in the late Early Badenian (NN5 and Upper Lagenide zones) from the direction of Slovenia and the Styrian basin. Thick sequences of predominantly pelitic deposits cover the continental beds. While the sediment accumulation was very intensive in the West (120 to 250 m/my in the Zala and Little Hungarian Plain basins), until in the eastern sub-basins the deposition of Middle Miocene series is much slower (50 to 100 m/my). They might have been starving deep basins, but it is not easy to decide, since there are no reliable data on the Badenian and Sarmatian paleodepths. Due to the Mid-Miocene climatic optimum also calcareous deposits appear at the basin margins (Leythakalk, Tinnye Lst).

The subsidence stopped for a while and compression and uplift might have occurred in the latest Sarmatian or earliest Pannonian, since also the uppermost Sarmatian beds have been involved into the basin inversion and denudation. This is why no paleontologically proven continuous transition is known between the Sarmatian and Pannonian sequences.

Pannonian to Pontian

The final isolation of the Pannonian basin-system from the world-seas led to the forming of a slightly brackish lake („Lago Mare”). A new extensional event resulted in abrupt deepening in the sub-basins inherited from the Middle Miocene. Thin pelitic bathyal deposits of Endrőd Marl (also calcareous marls) and turbiditic sequences of Szolnok Fm. formed in the deep depressions. Subsequently, due to the continuing extension almost the whole area of Hungary has been flooded by the Pannonian lake. From cca. 9 Ma on, the intensive siliciclastic sediment supply exceeded the rate of basin subsidence. A set of deltas filled up the Pannonian basin prograding from North toward the South. This shallowing up is reflected by the upward coarsening of the grain size in the Pannonian-Pontian sequences.

The focus of deposition migrated from the W-NW toward S-SE slowly. The accumulation rate of deposits is cca. 600-800 m/my in the Little Hungarian plain basin, cca. 350-600 m/my in the Zala basin, cca. 600-1000 m/my in SE-Hungary.

By the beginning of Pliocene most parts of the Pannonian basin-system became dryland, although the subsidence in large regions proceeds up to now among continental conditions

DEVELOPMENTS OF FRESHWATER BIODIVERSITY DURING THE LATE CENOZOIC: IMPACT OF GEODYNAMICS AND CLIMATE ON HOTSPOT FORMATION

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Freshwater species richness hotspots are unevenly distributed across the planet. Only few centers of biodiversity exist today, limited to the long-lived lakes on the Balkan peninsula and Lake Caspia. Quite contrary is the distribution of freshwater hotspots in the Miocene and Pliocene, where huge long-lived lakes existed with extremely high diversities and degrees of endemism. The causes for this discrepancy have not been assessed so far. Based on a huge dataset of gastropod distributions in more than 1,300 Miocene to Recent freshwater systems, we demonstrate that the mere existence and evolution of species richness hotspots are strongly related to Europe's geodynamic and climatic history. Both past and present hotspots are linked to the formation and persistence of geological basins or separation of present basins or embayments from the proto-Mediterranean or Paratethys seas. A hotspot's individual faunal development is associated with temperature and lake surface area.

During the icehouse climate and vast glaciations of the Ice Ages, freshwater biodiversity sustained a severe decline. We find strong support that the distribution of modern European limnic gastropods still carries the imprint of the last Ice Age. Although the snails' dispersal capabilities are considered to partially subdue the historical signal, the differences in species composition and richness are still quite obvious pointing towards a gradual process of species recolonization after deglaciation. Hence, gastropod distribution among the majority of modern lakes is a young pattern triggered by the ice shield retreat in the latest Pleistocene and subsequent formation of post-glacial lakes. The presently existing hotspots, however, are related to long-lived lakes in pre-glacially formed, permanently subsiding geological basins.

STRUCTURAL DEVELOPMENT OF THE DRAVA BASIN AND THE RELATED HYDROCARBON FIELDS IN THE BARCS REGION

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The Drava basin is situated in the southwestern portion of the Pannonian basin, on the border of Croatia and Hungary. It is an important hydrocarbon bearing territory (Fig. 1). The basin is a deep depression filled with 5-7 km thick Neogene sediments. The basement is composed of Variscan metamorphite, Late Carboniferous molasse and Mesozoic shallow marine carbonates and metamorphic rocks (Haas et al., 2010) (Fig. 2). The basin is the host of important source rocks and oil/gas reservoir rocks (Saftic et al., 2003). The fields can be detected within the Pannonian and pre-Pannonian basin filling sedimentary sequences (Fig. 2). All of the existing petroleum fields and prospective traps are related to structural features. The source rocks are Badenian and Pannonian age shales and marls, with type II. and III. kerogen in most cases (Baric et al., 1998).

The goal of the research is to gain accurate knowledge of the structural elements of the Drava basin by interpreting 3D and several 2D seismic surveys. Information from wells drilled in the study area, including well files and geophysical log data, was also included in the analyses. Some seismic attributes from the 3D survey were created using Petrel software (chaos, variance, antrack) for improved interpretation and illustration purposes.

In addition to the Alp-Carpathian evolution of the Pannonian basin during the Cretaceous, my study indicates that the area experienced younger episodes of deformation in at least two different phases. The reactivation of the Cretaceous nappe boundaries can be detected by the interpretation of the seismic surveys. This reactivation occurred during the Middle and Late Miocene, which caused the folding of the Middle Miocene and Early Pannonian layers. The stress field which could cause the reactivation should be characterized by NE-SW compression. These structures are very important in hydrocarbon entrapment. With the interpretation of the basement faults the pre-existing pre-Cenozoic map of Hungary can be clarified. The second deformation is around 6 million years old. Normal faults are related to it, which indicate a NE-SW extension. Moreover a dextral strike-slip fault with an advanced Riedel fault system can be recognised in the 3D seismic survey. The timing of the structure must be Pannonian as these strata are also affected. Since some of the faults reach the surface, this younger deformation may be a part of a neotectonic phase. The extension which is responsible for the faults is ENE-WSW. Besides these structures there are atectonic features. These faults are the product of differential compaction, which can be explained by the deposition of different thickness of sediments above the basement (Fig. 2). Polygonal faults can also be recognised in the shelf slope sediments.

The hydrocarbon fields are located above the basement highs, which were caused by the reactivation of the Cretaceous faults, the faults of the young deformation and compactional differences. These traps are only found in the lower sediments below the shelf slope formations. This means that the faults are sealing within the shelf slope section and shallower sediments, while also providing hydrocarbon migration pathways into the lower sedimentary sequence (Fig. 2).

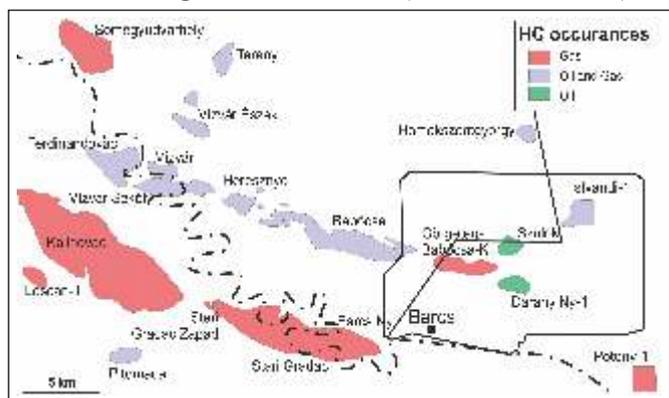


Fig. 1.: Map of the hydrocarbon occurrences on the study area with the location of the cross section

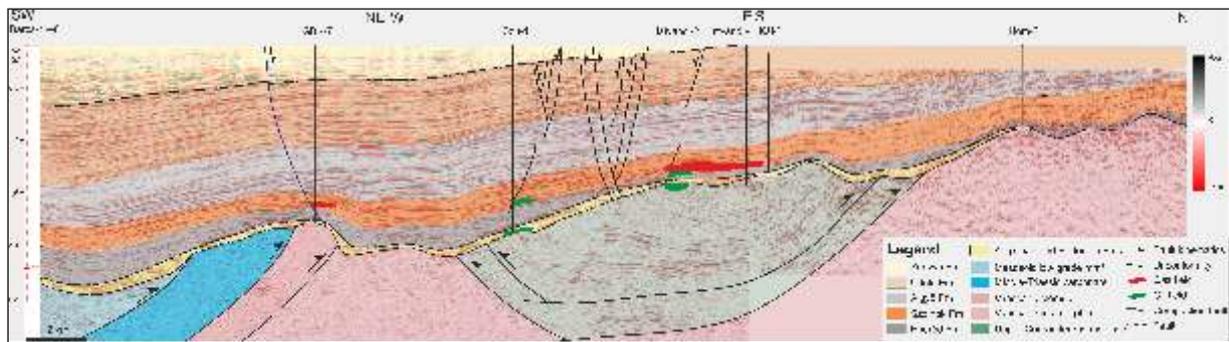


Fig. 2.: Geological cross section of the study area with the existing hydrocarbon fields and structural elements, the track of the section is presented in Fig. 1.

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THE AGE OF THE BADENIAN/SARMATIAN EXTINCTION EVENT – NEW INSIGHTS ON THE CHRONOLOGY AND THE PALEOGEOGRAPHY OF THE MIDDLE MIOCENE PARATETHYS REALM

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The Badenian-Sarmatian Extinction Event (BSEE) is considered to be the strongest faunal turnover in the history of Central Paratethys (Piller 2007). It marks the loss of open marine ecosystems and their replacement with restricted environments in which an endemic, Paratethys specific fauna develops and thrives.

Determining the age of the event is problematic due to frequent stratigraphic gaps at the BSEE level and as a result most of the current age models rely on correlations with global events. It is considered that the BSEE is caused the restriction of the connections between Central Paratethys and the open ocean (Rögl 1998). Correlations with various global events that could have reduced the connectivity are therefore used in dating the BSEE. This has led to age models for BSEE that vary between 12.7 and 13.32 Ma. However, the chronostratigraphic evidence for these correlations is scarce and prevents an in-depth understanding of the triggers and nature of the event.

We focus our study on key sections from a deeper basin of Central Paratethys, the Romanian Carpathian Foredeep (Fig. 1). Using an integrated stratigraphic approach that combines paleomagnetism techniques (magnetostratigraphy & rock-magnetism) and biostratigraphy (foraminiferans & nannoplankton studies) we have developed an age model that places the BSEE at 12.65Ma. The continuous Badenian-Sarmatian sedimentary succession used for dating the event provides more information on the duration and the nature of the BSEE while the age allows a more precise correlation with the global events for an insight on the potential triggers of the Badenian Sarmatian Extinction Event.



Fig1. Location of the Tisa Section. Paleogeography of the Paratethyan Basins around the BSEE. Central Paratethys and the relevant sections used for dating the BSEE (medallion). Abbreviations for the Central Paratethys sub-basins: CF - Carpathian Foredeep, ESB - East Slovak Basin, GB - Getic Basin, PB - Pannonian Basin, SPB - South Pannonian Basin, STB - Styrian Basin, TB - Transylvanian Basin, VB - Vienna Basin

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TSUNAMI DEPOSITS IN THE SARMATIAN CENTRAL PARATETHYS?

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Distinct horizons of a few cm-metre sized limestone boulders can be observed within the Sarmatian lime sand successions around Budapest. The shape of the boulders are often elongated with the long axis being parallel to the stratification. The boulders are more or less rounded and can be encrusted by microbial coating. They can be accompanied by 1–8 cm large quartz pebbles. The thickness of the boulder layers can reach several 10s of centimetres. They can be observed in a number of outcrops from Zsámbék to Kőbánya. The most boulder horizons, seven in number, can be seen in the limestone quarry near Sósút.

The phenomenon can be noticed on the Sarmatian carbonate platform from the horizontal very shallow water near land strata to the steeper basinward part of the clinoforms. Within the horizontal layers the boulders are well rounded and mostly encrusted (e.g. Biatorbágy, Gombaszikla). According to Cornée et al. (2009) the crust consists mostly of red algae, subordinately serpulids, nubeculariids és microbialites.

The boulder layers generally settle on a low-angle truncation surface within the upper, steeper part of the clinoforms, but they can be intercalated in the lower, low-angle part of the clinoforms. The steeper stratification of the clinoforms continue above the boulder layers. The boulders are less rounded and encrusted to a less degree than the ones within the horizontal strata in Biatorbágy. Imbrication indicating a basinward transport direction can also be observed. The clasts are badly sorted and are mixed with coeval lime sand. The limestone boulders can be grouped in certain parts of the clinoforms.

As for their formation, the boulder horizons have probably developed in several steps. Coastal limestone cliff pieces were ripped up by storm wave action, then rolled and rounded by wave action. Meanwhile, the boulders became microbially encrusted. The rounded and encrusted boulders together with freshly ripped-up clasts and terrestrial quartz pebbles were picked up by a sudden high energy wave and removed basinward. The moving sediment truncated the upper part of the clinoforms and part of the boulders were deposited on this erosional surface. Another part of the unsorted material reached the deeper, low-angle part of the clinoforms and settled there embedded in the normal sequence.

What could the sudden high energy wave have been?

The question is, what force could pick up the often 50–100 cm large rock bodies and transport them even as far as a few hundred metres: a huge storm or a tsunami?

Storm waves and tsunamis can both generate deposits of large grain size (Weiss 2012). Tsunamis result in unsorted sediment layers, while storm deposits are organised in rows along the breaker or in distinct areas. No such linear or areal grouping can be seen in the boulder horizons.

In this case we can speak of backwash deposits. According to Le Roux et al. (2008), Cantalamessa, Di Celma (2005) and Smit et al. (2012) backwash tsunami deposits are characterized by an erosional surface underneath the tsunami layer, an outstanding energy unit (grainsize is much larger than in the surrounding layers), material from the dryland, local ripped-up material and bad sorting. These features can all be observed in the Sarmatian boulder layers.

If tsunami, what was the trigger?

Underwater landslides merely cause a local effect in one bay or subbasin (Ward 2001). Since limestone boulder horizons occur in many places around Budapest, this idea has been ruled out. The area was tectonically active during the Sarmatian (Fodor et al. 2000) and volcanic activity was also present, so these seem to be the most likely triggers for tsunamis.

Although sediments transported landward can much better be studied in connection with recent tsunamis, the outstanding importance of backwash transport is suggested by the research of MacInnes et al. (2009) who suppose the amount of sediment transported basinward to be much larger than the amount of deposit moved landward. According to Smit et al. (2012) the effect of tsunamis can be best studied in sediments deposited in 10–200 m water depth, immediately below storm wave base. The depositional depth of the Sarmatian limestone was about 25 m at most.

There is still a lot of research to do in order to prove the presence of tsunami deposits in the Sarmatian. The system of characteristic features of backwash tsunami deposits has not been set yet (Smit et al. 2012), it needs to be worked on.

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LOWER MIOCENE (EGGENBURGIAN AND OTTNANGIAN) SANDS IN THE LOWER AUSTRIAN MOLASSE BASIN

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In the Early Miocene (late Ottnangian), a global sea level drop and the continuous rise of the Alps lead to the regression of the Paratethys sea and to the sedimentation of the Upper Freshwater Molasse. In the Lower Austrian Molasse Basin, this event is represented by yellowish-brownish to greyish white mica-rich and carbonate-free sands and silts with clayish interlayers, formerly called Oncophora Beds, which crop out between St. Pölten and Tulln. A new lithostratigraphy combines these sediments, now called Traisen-Formation (TF) together with the Dietersdorf Formation within the Pixendorf Group.

Drill cores from OMV-wells predominantly from the NE show hundreds of meters thick sequences of pelites with intersections of sands interpreted as representing the OB. Contrary to the mainly brackish TF, a turbiditic marine deeper-water environment is inferred. Based on a detailed well section, this sandy deeper-water interval of the former Oncophora Beds is renamed as Wildendürnbach Member (WM).

An OMV-funded project investigates the relationship between these sediments, their provenance, facies and stratigraphical and chronological range. Mineralogical investigations (XRD, thin section, microprobe) show homogeneous compositions of sands and pelites. Therefore large variations of the source rocks seem unlikely.

Whole rock chemistry, carbonate content measurements and biostratigraphic investigations on samples from the WDK4 and Schaubing wells indicate an interval of carbonate and salinity crisis (B/A1* and TOC/S proxies) barren of fossils. This interval starts at the top of the so called "Fischfazies" or "Meletta Schlier".

The presented results indicate a basinal facies of the Upper Freshwater Molasse in Lower Austria renamed as Wildendürnbach Member (WM). The interval is characterized by a salinity and carbonate crisis and a change in clastic composition at the onset.

NEW RESULTS OF GEOLOGICAL AND GEOCHEMICAL INVESTIGATIONS AND BASIN MODELLING OF THE NEOGENE SEQUENCE, SOUTHERN PART OF THE GREAT HUNGARIAN PLAIN, HUNGARY – CASE STUDY

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The last public basin model focusing on the hydrocarbon exploration area in the southern part of Danube-Tisza Interfluve was prepared at the end of 80's using old approach and technology. Ever since significant amount of new information emerged: new seismic, drilling and geochemical results have been made.

During our work 1D and 2D models of subsidence and maturation history have been prepared for the Neogene sedimentary succession. With the help of the numerical basin modelling we were able to simulate and image the geological processes during development of each sedimentary sub-basin. Our goals with the current modelling are to determine the hydrocarbon potential, the time of hydrocarbon generation, the volume of generated hydrocarbon and the potential accumulations.

The data for the modelling was derived from seismic data, drilling results and literature. Based on this dataset the input geological/geochemical model was developed using the seismic and stratigraphic interpretation (Fig.1.). The basin models have been prepared with the help of PetroMod software.

The studied sub-basins formed during the syn-rift phase of the Pannonian basin development, along strike-slip zones – however under different time and geological setting. First one of the sub-basins was filled up with deep-marine-to-nearshore sediments in the Karpatian stage. It is overlain by a thick conglomerate succession which is probably related to a Gilbert-type delta system (Lemberkovics, 2014), of Karpatian age. In the Badenian stage carbonate rich formations deposited in the shallower regions as the first result of the marine transgression. As heteropic facies, deep marine pelitic sediments accumulated in the deepest part of the depocenters. During the Late Badenian and Sarmatian stage there was either non-deposition or the sediment was partially/completely eroded by the further geological processes. Last, the Pannonian sedimentation cycle is represented by a complete sequence of the well-known shelf-progradation (Magyar et al., 2013), from the deep water marls to the alluvial plain deposits, with large inhomogeneity in their spatial and facies distribution.

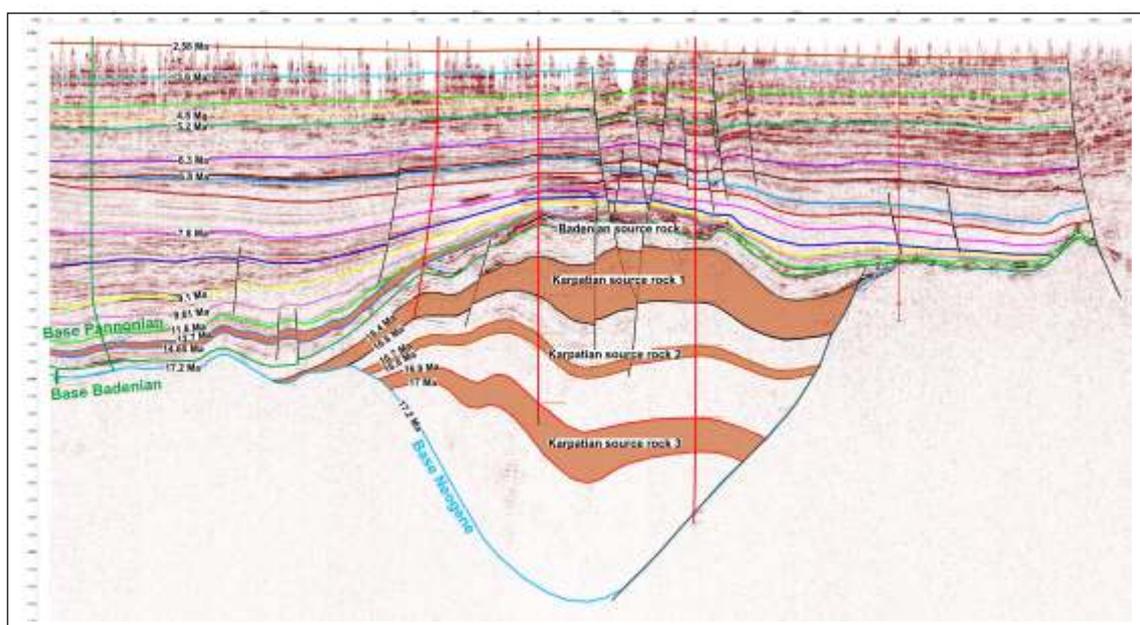


Fig.1.: Seismic and chrono-stratigraphical interpretation of Neogene sediments of the investigated sub-basins

In the studied area source rocks are the organic matter rich parts of the Karpatian and Badenian sediments. During the modelling higher and lower heat flow profiles have been applied. These profiles are the results of the calibration to the temperature and measured vitrinite reflectance values in the 4 investigated wells. In one case the heat flow was calibrated to the Badenian, the other case to the Karpatian source rocks.

It was concluded that one part of the investigated area has higher thermal up-heating and – obviously – the maturation of the source rock layers could reach the top of oil window much shallower depths here compared to the adjacent sub-basins and/or the average in Hungary. Comparing the 1D basin models prepared by the authors and former experts (Szalay et al., 1987) for one of the studied sub-basins, it can be determined the top of oil window is significantly shallower generally in the new model.

To solve the realized geological uncertainties and for the better understanding of the hydrocarbon generation perspectives a 2D regional maturation model is under construction for this geologically complicated exploration acreage.

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ECHINODERM BASED UPPER BADENIAN PALEOECOLOGICAL RECONSTRUCTION IN THE REGION OF BUDAPEST

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The rich Echinoidea and Crinoidea fauna of the Badenian (Middle Miocene) from Budapest is well known since more than a hundred years. The main aim of this study was to revise historically collected echinoids (in the collection of Geological and Geophysical Institute of Hungary) from the vicinity of Örs vezér square and to classify the newly collected fossils, moreover to carry out the palaeoenvironmental reconstruction of the different localities.

Altogether more than 200 specimens were studied from the Upper Badenian Leithakalk Formation, which consists of sandy limestone, calcareous loose sandstone with volcanic clast and/or kalkarenit without terrigenous or volcanic clast.

For the detailed taxonomic establishment morphometric studies were done to recognize and interpret the inter- and intraspecific variability. Six characters (length, width, height, periproct to peristome, peristome to periproct distance and average length of ambulacrum) were measured on every specimen. Morphometric parameters were analysed with Principal Component Analysis and Ward Cluster Analysis. The ecological interpretation is based on the Badenian Echinodermata literature, recent analogies, taphonomic and facies analysis. The taxonomical revision proved the occurrence of 9 species within 9 genera instead of the previously established 15 species of 11 genera. These are the followings, in order of the frequency:

Parascutella gibbercula Deserres, 1829
Psammechinus dubius Agassiz, 1840
Parascutella vindobonensis (Laube, 1871)
Echinolampas hemisphaerica Lamarck, 1816
Schizaster karreri Laube, 1869
Spatangus sp. indet.
Psammechinus sp. indet.
Kieria semseyana Mihály, 1985
Echinocardium biaense Mihály, 1985
Echinocardium sp. indet.
Amphiope bioculata (Des Moulins, 1837)

Because of the morphometric differences between *Scutella hungarica* and *S. pygmaea* are not significant their range on PCA overlaps while in cluster dendrograms the specimens of the two species are mixed. Andreas Kroh described these species as the juvenile form of *Parascutella gibbercula*. Recent morphometric studies confirm this hypothesis.

At the locality Örs vezér Square the occurrence of *Clypeaster* and *Schizaster* indicate a deeper water environment with approximately 30 m water depth. The water presumably was non-disturbed based on the presence of *Antedon*. The specimens are usually larger, and well preserved, while a few hundred meters away at the locality Gyakorló Street the dominant genus is the small *Parascutella* (80%). This form prefer shallow water environment. The presence of *P. gibbercula* suggests a very shallow (0-20 m) environment. Based on the ecological requirements of Echinoderms a deeper water bioherm and a calm lagoon environment were detected.

The recent study served important new data about the taxonomical and ecological variability of the last representatives of the Central Paratethyan Echinodermata fauna.

EASTERN PARATETHYS MIOCENE DEPOSITS, MOLLUSKS AND NANNOPLANKTON OF THE NORTHERN IRAN

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Eastern Paratethyan deposits are known on the Caspian seaside of Iran (Mazandaran Province) from beginning of 20th century (Golubjatnikov, 1921). Geological map of this province was compiled by Russian geologists after the Second World War (Saidov, Kushanin, 1947). They had mapped Maykopian (Oligocene – Early Miocene), Chokrakian, Karaganian, Konkian, Sarmatian (Miocene), Akchagilian, and Apsheronian (Pliocene – Lower Pleistocene) horizons (later regiostages). Iran Geological Survey mapped this territory at 70th, Paratethys stratigraphic scale did not used. We had possibility to work on three sections in Mazandaran (Babol, Talar, Alamdeh) at September, 2013, after Conference ICME2013 in Zanjan. Main results were received on the Babol Section.

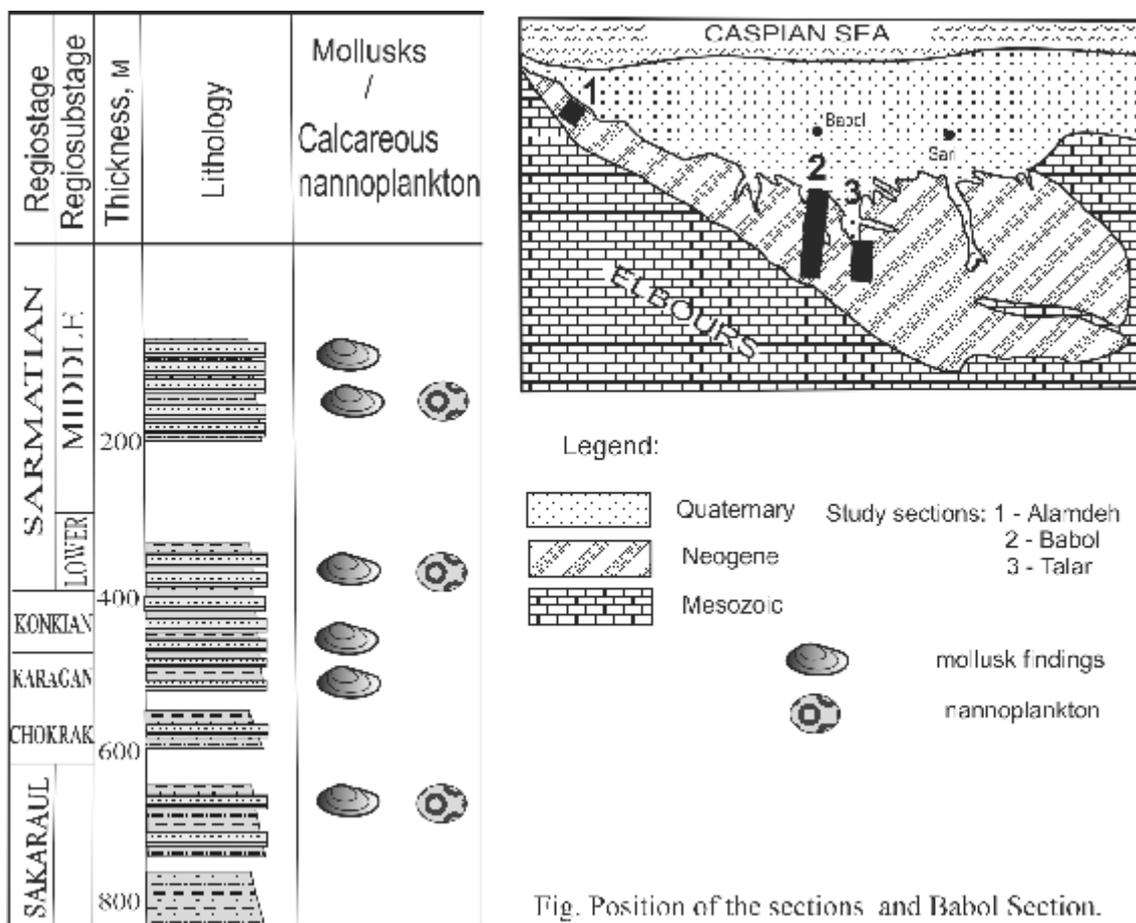


Fig. Position of the sections and Babol Section.

Lower Miocene. Upper Maykopian deposits represented by shallow sandy-clayey facies and sandstones with mollusk shells: «*Fragum*» *semirugosum* (Sandb.), *Laevicardium spondyloides* (Hauer), *Anadara sakaraulensis* (Popov), *Glossus cor* (L.), *Callista lilacinoides* Schaffer, *Calistotapes vetula* (Basterot), *Dosinia exoleta* (L.), *Lyonsia macai* Kharatishvili. All this association is typical for the Sakharaulian Regiostage of the Georgia. Calcareous nannofossils were found from the same deposits and the association indicating the part of the NN1-NN2 Zone. Decisive for such dating is the co-occurrence of *Triquetrorhabdulus challengerii* Perch-Nielsen, 1977 and *Sphenolithus conicus* Bukry, 1971.

Middle Miocene. Chokrakian deposits (according to Saidov, Kushanin, 1947) represented by red-color clays mainly continental genesis without fauna. Karaganian sandy-silty sediments included abundant *Spaniodontella gentilis* (Eichwald) and *Mohrensternia*, very typical for this regiostage. Transition interval between Karaganian and Barnea Beds characterised by mollusks - *Spaniodontella (Savanella) sp.*, *Barnea cf. uiratamica* (Andrusov), *?Ervilia sp.*, and rare fragments of *Braarudosphaera bigelowii?*. Barnea Beds of the Konkian are presented by sands and sandstones with abundant *Barnea uiratamica* Ossipov and *Barnea ustjurtensis* (Eichwald). Layers with polyhaline Konkian fauna are absent.

Sarmatian sandstones include typical Sarmatian bivalves: *Maetra eichwaldi* Laskarev, *Maetra andrussovi* Kolesnikov, *Musculus cf. sarmaticus* (Gatuev), *Plicatiformes praeplicata* (Hilber), *Plicatiformes plicata* (Eichwald), *Obsoletiformes lithopodolica* (Dubios), *Venerupis (Polititapes) vitaliana* (Orbigny), *Gomphomarcia naviculata* (R. Hoernes), but besides *Tellina (Laciolina) cf. pretiosa* Eichwald, *Corbula gibba* Olivi, which are known from more polyhaline Konkian layers only in other parts of the Eastern Paratethys. Calcareous nannofossil assemblage consists of *Coccolithus pelagicus*, *Helicosphaera carteri*, *Sphenolithus sp.*, *Reticulofenestra sp.*, *Calcidiscus leptoporus*, *Discoaster deflandrei*, *Coccolithus miopelagicus*. Enough diverse composition of mollusks together with the presence of nannofossil assemblage indicates of distinct marine influx.

Middle Sarmatian sandstones and silts include typical Sarmatian bivalves: *Maetra ex gr. vitaliana* (Orbigny), *Donax dentiger* Eichwald, *Plicatiformes plicata*, *Obsoletiformes sp.*, *Venerupis (Polititapes) vitaliana*, *Gomphomarcia naviculata*, and more polyhaline species - *Parvicardium ex gr. exiguum*, *Solen sp.*, *Cultellus sp.*, *Corbula gibba*, which are unknown from other regions of the Eastern Paratethys. In the same layers *Reticulofenestra sp.*, *Coccolithus pelagicus*, *Helicosphaera carteri*, *Sphenolithus sp.* were founded.

Based on these data we proposed existence of marine corridor between the Eastern Mediterranean and Transcaucasian part of Paratethys before mid-Sarmatian.

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DIATOMS IN THE SARMATIAN, MAEOTIAN AND LOWER PONTIAN (THE TAMAN PENINSULA)

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Diatoms have become one of the largest groups of microbiota in the upper Miocene of Eastern Paratethys with the advent of communication between the Dacian and the Black sea basins in the Sarmatian time.

For stratigraphic diatom study we used the regional zonal scale of Kozyrenko & Temniskova-Topalova (1990). During the study of Taman sections the scale was worked out in detail, the composition of zonal assemblages is defined more precisely. The Middle and Upper Sarmatian, Maeotian and Lower Pontian diatom deposits of Taman section were divided into regional zones *Actinostephanus podolicus* (upper part of Middle Sarmatian), *Achnantes brevipes-Navicula zichyi* (Upper Sarmatian), *Thalassiosira maeotica* (Lower Maeotian), *Cymatosira savtchenkoi* (Upper Maeotian) and layers with *Actinocyclus octonarius*. The base of each zone was carried out by appearance of species-index.

The layers with different ecological types of diatoms, caused by transgressive-regressive cyclicity of the Basin, were distinguished in volume of each zone. Between the Middle and Upper Sarmatian, Upper Sarmatian and Maeotian, Upper Maeotian and Pontian the layers with anomalous composition were identified. Together with endemic Paratethys species, comprising most part of assemblage, open-marine and oceanic species, being markers of oceanic zones by diatoms with datings of appearance and disappearance were found. Occurrence of certain species of oceanic diatoms in the Middle-Upper Sarmatian, Maeotian and Lower Pontian makes possible a direct correlation of the respective sections and those of the Mediterranean basin. (Radionova, Golovina, 2011)

There was a continuous change of diatom associations installed in the Zelensky Hill –Panagia Cape section and appeared in the interval zones *Actinostephanus podolicus* - *Achnantes baldjickii* var. *podolicus* and *Achnantes brevipes* - *Navicula zichyi*, i.e. full and continuous sequence of sediments Middle - Upper Sarmatian and the transition to Maeotian.

Sr 2 zones *Actinostephanus podolicus*.

Sr2.1. Dominated by centric probably planktonic forms - *Actinostephanus podolicus*, *Cocconeis doljensis*, of benthic species are most frequent *Grammatophora sp.sp*, *Cocconeis scutellum.*, *C.grata*, *Achnanthes baldjickii* var. *baldjickii* + var. *podolica*. Other representatives of benthic groups - *Diploneis*, *Mastogloia*, *Campylodiscus* et al. are rare,

Sr2.2. have approximately the same composition as diatoms, but domination by benthic flora and plankton species is rare. High numbers have *Achnantes baldjickii* + var., *Cocconeis scutellum* + var., *Grammatophora marina*, *Amphora proteus*; somewhat inferior to them in numbers *Achnanthes brevipes*, species of the genera *Diploneis*, *Mastogloia*. Prevalence of fouling and bottom dwellers - genera *Cocconeis*, *Achnanthes*, *Grammatophora marina*, *Mastogloia*, *Diploneis* et al., which indicates shallow-water deposits.

Comprehensive study of the microbiota in the Sarmatian and Meotian identified several levels of marine microbial associations related to short-term marine pulses.

Sr2.3. - Sr3.1. At the turn of the Middle-Upper Sarmatian the important oceanic diatom markers *Thalassiosira burckliana*, *Thalassiosira coronifera* var. *astra* and *Nitzschia fossilis* were found.

Sr3. Zone *Achnantes brevipes* – *Navicula zichyi*. Within this zone layers alternate with the benthic species *Achnanthes brevipes* and species of the genera *Rhopalodia*, *Entomoneis* *Amphora*, *Amphiprora* being dominant. In others layers there is total number of plankton freshwater and brackish species *Actinocyclus* - *Actinocyclus* aff. *krasskei* There are members of the genus *Pliocaenicus* (?).

Sr3 - M1. The transition from the Sarmatian to the Meotian traced to 20m pack of gray clay lying under Briozoa bioherms. Here is an alternation of layers containing a typical upper Sarmatian brackish-water flora with *Actinocyclus* and the layers which are marine plankton. Among the marine diatom species oceanic species were found *Thalassiosira grunowii*, *Coscinodiscus a steromphalus*, several types *Hyalodiscus*, *Actinoptychus splendens*, *A. senarius* and marine intertidal species - *Endictya oceanica*, *Paralia sulcata*, *Pseudoparalia westii*. This is probably the most salinity Late Sarmatian flora, already close to Maeotian.

M1 zone *Thalassiosira maeotica*

M1-1 The Base of Meotian marked by the appearance of planktonic *Thalassiosira* association with species-index - *Thalassiosira maeotica*. **M1-2** In Most Maritime Association included *Nitzschia miocenica* and silico flagellate *Distephanus speculum* appear, relating to stenohaline marine microorganisms. **M1-3** – regressive impulse. **M1-4** reflects an increase seaward. There are rare species of the oceanic zone *Thalassiosira convexa*: *T. praeconvexa* and species-index *T. convexa*. Above appears here *Symatosira savtchenkoe*.

M2 zone *Symatosira savtchenkoe*

M2-1 The lower strata of the Upper Maeotian contains brackish and freshwater diatoms. The most numerous group of the diatom genus *Actinocyclus*, including a few brackish-marine species and several freshwater ones - *Act. determinatus*, *Act. styliferum*, the brackish-water species *Stephanodiscus* and *Cyclotella* genera. *Coscinodiscus jambori* and *Ellerbekia arenaria* var. *teres* (*Melosira teres*) are the most common species of the assemblage. M. Hajós described them as marker species of the Pannonian (Hajós, 1985)

The benthic diatoms include *Eupodiscus* sp., *Endictya oceanica*, *Hyalodiscus scoticus*. A variety of species of freshwater genera *Epitemia* and *Tryblionella* are large forms of sells. Brackish *Nitzschia punctata* with several subspecies are distributed throughout the column. Few species characteristic for Pannonian of Hungary - *Fragillaria crassa* Hajos, *Diploneis esthereia* Hajos, *D. splendida* (Greg.), *Mastoglia dubravisensis* Hajos were found.

"Transitional strata" (according to Radionova, Golovina, 2011), tripartite strata - marine shale interbedded with laminated calcareous diatomite corresponding to the upper part of the Upper Maeotian – Lower Pontian

M2-2 and M2-3 strata include open-marine species *Azpeitia aff. komurae* and *Coscinodiscus perforatus*. Evxinian endemics *Actinocyclus aff. paradoxus*, *Rhyzosolenia bezrukovii*, *Hemiaulus* sp. appear in this part of the section. Several specimens of *Thalassiosira convexa* Zone; *Thalassiosira praeconvexa*; *Thalassiosira convexa*, *Thalassiosira miocenica* were found.

P1 strata contains association diatoms where *Actinocyclus octonarius* dominated.

The transitional Upper Maeotian–Lower Pontian relatively deep-water sediments were formed at the time when Eastern Paratethys was connected with other marine basins. Diatom assemblages Accumulation of these transitional facies in the Taman Peninsula sections corresponds to the event of Mediterranean marine waters invasion into the Eastern Paratethys basin. Two stages of this invasion are distinguished: in the first one the connection between basins was rather permanent, while in the second one its character became pulsing and not stable. Maximum duration of the invasion is estimated from 6.3 to 5.9 Ma and belongs to the Early Messinian – to pre-evaporate deposits and lower part of lower evaporate deposits

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UPPER BADENIAN PALEOENVIRONMENT OF THE MARGINAL MARINE SEDIMENTS (INTERPRETATIONS BASED ON MEIO AND MICRO FAUNA FROM THE DUBOVÁ LOCALITIES)

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During excavation work for building of winery in Dubová in 2008, species-rich and specimen-rich assemblages of foraminifers, molluscs, anthozoans, ostracods, bryozoans and other invertebrates, vertebrates, palynomorphs and nanoplankton of the Middle Miocene age were obtained. This locality is situated in the north-western margin of the Danube Basin (in the Blatné Depression) at the eastern foot of Malé Karpaty Mountains (Hladilová et al., 2013; Jamrich, 2013).

High resolution sampling was used for examining of this 2,5 m thick lithological section cut in the clays, silts and sands of the Báhoň Formation. A striking accumulation of disarticulated valves of the *Crassostrea gryphoides* occurs in the middle part of the section. Valves of this giant oyster found at this locality are up to 35 cm long. This study is focused on the synthesis of foraminifers, molluscs and palynomorphs. The most abundant molluscan taxa are *Sandbergeria perpusilla*, *Loripes (Microloripes) dentatus*; *Clithon pictus tuberculatus* and *Bittium reticulatum*.

Foraminiferal associations could be divided into three distinctive groups. Group 1, where *Elphidium crispum* is the most abundant species, is related to the harder bottom with algal and sea-grass carpets. Group 2, dominated by *Ammonia* and *Elphidium*, indicates environments with sea-grass coverage and more eutrophic conditions with possible lowering of the oxygen content. Group 3, with occurrences of the genus *Borelis*, could be related to algal-coral patch reef environments.

On the basis of the foraminiferal association and occurrence of the gastropod *Clithon pictus tuberculatus*, these sediments could be placed into the Upper Badenian *Ammonia vienensis* Biozone as equivalent of *Bulimina-Bolivina* Zone.

Sediments show a fining-upward trend indicating a decrease in water energy and/or increase in water depth with correlation to increasing of TOC. The co-occurrence of the patches of the *Siderastraea italica*, *Palaeoplesiastraea desmoulinsi*, *pectinids* and *Crassostrea gryphoides* is interesting due to their different salinity preferences.

Autochthonous palynomorphs assemblage is documented by common microforaminiferal linings and dinoflagellates. These are associated with allochthonous terrestrial subtropical flora presented by longer distances flying *Cathaya* and *Pinus*, as well as coastal swamp vegetation type with the *Myrica* and *Glyptostrobus* dominance.

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THE MIDDLE MIOCENE TRANSGRESSION: NEW DATA FROM THE VICINITY OF BOR, EASTERN SERBIA

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The early Middle Miocene transgression is one of the most important events that occurred in the Miocene. It is much evidence of this and there are plenty of published works. In this paper, we will show the newest results from the westernmost parts of the Dacian basin, eastern Serbia.

The Upper Cretaceous and Miocene units, discovered by exploration boreholes in wider area of Bor, were subject of detail sedimentological, structural, mineralogical, and biostratigraphical studies. Complete succession of Cretaceous and Miocene units was mapped in eleven of twelve boreholes, whereas in one of them was noted and studied only the earlier Miocene unit (FMTC 1337). Total 4622 m were mapped and more than 300 samples were taken. According to results acquired during mapping of drilling intersections, six units have been distinguished. The Upper Cretaceous units are andesites and other volcanoclastics, marls, which are considered as the Senonian age and the so-called the Bor clastites (conglomerates and sandstones) that are in respect to marl superpositionally younger but also Senonian. Miocene units are divided into: 1- Basal coarse-grained clastites, 2 - Fine-grained clastites and marls and, 3 - gravels and sands (Table 1).

No	Name of unit	Chronostratigraphy
1	Gravels and sands	? Sarmatian
2	Fine-grained clastites and marls	Badenian - Sarmatian
3	Basal coarse-grained clastites	? Basal Middle Miocene
4	Bor clastites	Upper Cretaceous
5	Marls	Upper Cretaceous
6	Andesites and their volcanoclastics	Upper Cretaceous

Different basement (footwall) resulted from paleo-relief, which was modified by erosion since Upper Cretaceous, throughout Paleogene, until Miocene. Consequently, Miocene units may overlie either andesites and their volcanoclastics, or Upper Cretaceous marl, and finally Bor clastites.

The basal one Miocene unit represented by coarse grained-clastites. Unit was noted in seven boreholes. Generally, the total thickness reaches from a few meters to 26 meters. It overlies the Bor clastites (FMTC 1109, 1210, 1339 and 1346), or the Upper Cretaceous marls (FMTC 1213) as well as andesitic volcanic and volcanoclastics rocks (FMTC 1337 and FMTC 1340). This unit should be subject of the future studies that are expect in this area. Simultaneously, the timing of the sedimentary infill in the wider area should be important goal of the following investigations as well as the comparison this event to the similar one from the other part of the Dacian basin.

Based on the first results of biostratigraphic analysis, the Middle Miocene flooding in the studied area was occurred in the late Badenian (middle part of the Miocene units, so-called the „Miocene fine-grained clastites and marls”). Preliminary results based on marine fossils (predominantly foraminifers) indicate the presence of the Upper Badenian (Popović & Gajić, 1969). Dominant species are *Ammonia* ex gr. *viennensis* (d'Orb.), *Ammonia* ex gr. *beccarri* Linne, *Anomalinoides badenianensis* (d'Orb.), *Anomalinoides* sp., *Asterigerinata planorbis* (d'Orb.), *Bolivina* cf. *dilatata* Reuss, *Bolivina dilatata maxima* Cicha & Zapletalova, *Bolivina* sp., *Cancris auricularis* (Fichtel & Moll), *Cibicidoides ungerianus* (d'Orb.), etc). It is the best

documented in the borehole FMTC 1109 (the total thickness of unit reaches up to 305 meters) where the Badenian marine fauna was found in the deepest samples (ca. 280-354 m). Badenian-Sarmatian transition is gradual and located between 280-240 meters. Samples which come above the 240 m belong to the lower Sarmatian. So, the presence of transitional Badenian-Sarmatian layers (Filipescu, 2004) or so-called the Buglov horizons (Džodžo-Tomić 1963, 1969, 1970; Pishvanova et al. 1970) in this borehole is documented. Previously, deposits that correspond to this unit were not observed at the surface, particularly in the study area. Their findings could be a motivation for the new investigations and possible dating of the marine transgression in the wider area.

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THE EARLY MIDDLE MIOCENE TRANSGRESSIVE DEPOSITS FROM THE SERBIAN PART OF THE PANNONIAN BASIN - AN OVERVIEW

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General evidences concerning the marine Miocene transgression during the early Middle Miocene are well-known. Yet, there are lots of misunderstandings in relation with the timing of the first Miocene marine flooding in territory of Serbia. Most of the studied outcrops or shallow drill sections indicate that the great transgressive episode was during the Badenian age. The best proofs for the mentioned events come from the Jadar basin, Fruška gora Mt., Belgrade city area and its vicinity, Kolubara-Tamnava basin, Neogene depression between Arandjelovac and Kosmaj Mt., Morava graben, Resava depression, Mlava basin, Drmno depression (Krstić, 1996). Nearly all of the authors report that marine Badenian sediments overlie the freshwater pre-Badenian deposits. The Badenian sediments are characterized by large facies diversity, which is a consequence of various sedimentation conditions in the coastal area of the Badenian Sea. The following lithostratigraphic members are distinguished: 1) Conglomerates and sandstones with *Globigerinoides trilobus* Reuss., *Globigerina bulloides* d'Orb., *Globigerina quadrilobata* d'Orb., *Orbulina suturalis* Brönnimann, *Globigerina bilobata* d'Orb., *Cibicides dutemplei* d'Orb., *Cibicides ungerianus* d'Orb; 2) Sandstones, sandy marls and tuff-sandstones, representing the widest distributed type of marine Badenian on Fruška Gora, belong to Lower Badenian age, approximately; 3) Clays and clayey marls, developing in various stratigraphic levels of Badenian. In the lower Badenian, they are alternating with sandstones, and in certain places form the deep-water facies with pteropods (*Vaginella austriaca* KITTL.), cephalopods (*Aturia aturi* BAST.) etc; 4) Leitha limestones and sandstones – reef formations. They contain numerous fossils, and several varieties of limestones may be distinguished (e.g. lithotamnian, amphistegine, sandy, bryozoan, cerite, etc.); 5) Marls and plate-shaped marls of final parts of Baden turning into Sarmatian. All the mentioned units and their sedimentological features and very abundant and diversified fossil assemblages indicate onto at least two transgressive phases throughout Badenian time (Early and Late Badenian).

What's the base (footwall) for the mentioned Badenian deposits? Commonly, the different Badenian sediments cover undivided the continental-lacustrine Lower Miocene (so-called pre-Badenian) deposits (e.g. Slanci Formation, Vrdnik Formation). These deposits were the best studied on the northern slopes of the Fruška gora Mt., Belgrade city area, Valjevo-Mionica basin as well as in many small coal mines along the southern margin of Pannonian basin. These sediments transgressively and discordantly cover the various members of older, pre-Neogene base. In certain places, the relationship with the base of older formations is tectonic. Lower Miocene heterogenous clastic-carbonate sediments are colorful (dark- red, dark-grey, gray-green, etc) and include conglomerates, coarse to fine-grained sandstones, marls, silty marls, sandy marls and shales (e.g. Aleksinac basin). The total thickness of this formation reaches up to 500 m. However, a great package of these deposits up to 1500 m in thickness was noted in the Markovac depression (Morava graben, Dulić *et al.*, 2013). Furthermore, in the Drmno depression at the borehole Dr-1, the Lower Miocene sediments drilled at the depth of 2185 m (Janković, 1982). In northern part of the Morava graben (near Smederevo), the boundary between Badenian and Lower Miocene colorful series is located at depth of 1214 m (borehole Ra-1, Janković, 1982). On the other hand, there are places where the marine Badenian lies transgressively over the crystalline schists of the Serbo-Macedonian Massif (Proterozoic to Early Paleozoic) at a depth of 1445 m (borehole Sd-1 near Smederevo, Janković 1982). Poor fossil remains from these sediments (flora, freshwater ostracodes, fish remains, mammals) are not adequate for a precise biostratigraphic division. Yet, a few of domestic authors (e.g. Petrović, 1967) stated that in the Jadar basin (western Serbia)

the first Miocene marine ingression occurred in the Karpatian age (the mentioned as Helvetian). Similarly, based on the deep exploratory drilling in the area of the Požarevac - Danube area, Morava graben and Kolubara-Tamnava basin, some petroleum geologists from NIS-Naftagas Co. indicate the presence of the Ottnangian-Karpatian stage (Stanković et al., 1983; Gagić, 1990; Dulić et al., 2013). Their conclusions were based on the studies of calcareous nannoplankton, palynological assemblages and forams. The boundary between the Karpatian and Lower Badenian is very difficult to locate (e.g. similar rocks successions and depositional conditions). Nevertheless, a few seismic sections in the Požarevac - Danube area show the concordant and clear boundary between Lower Miocene and Lower Badenian deposits (Dulić et al., 2013). It is quite different in relation to the northeastern Bosnia and Herzegovina where the boundary is tectonic. It is very clear both on seismic sections and biostratigraphically (Dulić et al., 2013).

A very intensive tectonic activity during the Early-Middle Miocene led to development of the uplifted structures and erosional processes. However, it is reasonable to assume that the oldest marine sediments exist in the deep basinal structures (e.g. Jadar basin, Morava graben, northern Banat, etc.) covered by a few thousand meters thick series of Miocene sediments. It should be place for the final evidence of the pre-Badenian marine sediments. At the moment, these data are quite unreliable and it needs additional research particularly in the field of subsurface geology. On the other hand, the presented data and obtained results show necessity for the further interdisciplinary approach and more detail studies of the mentioned topics. Only then, we could be able to recognize the transgressive/regressive cycles and the initial Miocene marine flooding in Serbia.

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SEDIMENT PROVENANCE AND THE INFLUENCE OF PALEOENVIRONMENTAL CHANGE ON DEPOSITION IN THE NORTHERN DANUBE BASIN. BLATNÉ DEPRESSION CASE STUDY

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The Danube Basin is situated between the Eastern Alps, Western Carpathians and Transdanubian Range junction. In the North-west part a smaller finger like depocenter known as the Blatné depression yields Middle to Upper Miocene strata. The sedimentary fill is ranked into Langhian-Serravallian (Badenian, Sarmatian) up to Tortonian - Messinian (Pannonian) stage and is documented by: NN4, NN5 and NN6 calcareous nannoplankton zones; CPN7, CPN8 foraminifer zones (these are equivalents of global foraminiferal zones; N 9, 10, 11 and of the Mediterranean foraminiferal zones; MMi4a; MMi5 and MMi6). The Late Miocene is documented by relative superposition and by Beryllium isotope dating. During the initial rifting sedimentation in the depression began with basal conglomerates formed by local fan-deltas. In these conglomerates, Mesozoic carbonate rocks from the cover and nappe units of the Western Carpathians dominate. The content of Paleozoic crystalline rocks increase upwards, this indicates continual denudation of the emerged provenance area during the Langhian. The basin opening was accompanied by synrift volcanism what is reflected in deposition of tuffite lyres and volcanic epiclastic material. Additionally co-occurring of well sorted conglomerates and pebbly-mudstones points to a ongoing deposition by fan-deltas which was accompanied by gravity sediments triggered by rifting. During the early Serravallian mudstones prevail and near-shore to off-shore sedimentary conditions are assumed, they gradually pass into late Serravallian coastal plain environment with normal to brackish salinity. Sedimentation on the shallow shelf of the Lake Pannon followed during the early Tortonian postrift stage, and was subsequently replaced by relatively short-lasting deltaic environment and later by deposition on an alluvial plain. Minor Pliocene to Quaternary sedimentation is characterized by dominance of gravels and sands of fluvial channels.

Keywords: Middle and Upper Miocene, Danube Basin, Blatné depression, biostratigraphy, sedimentology, provenance of clastics, depositional systems.

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A DIFFERENT STRATIGRAPHIC APPROACH TO RECONSTRUCT THE KARPATIAN AND BADENIAN SEAS IN CENTRAL EUROPE

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The Paratethys sea region in Central Europe experienced many paleogeographic changes during the Early-Middle Miocene. The interplay between tectonics, basin infill and eustatic sea level variations caused the existence of different marine transgressions. In many localities marine sediments of the Early Miocene 'Karpatian' stage are discordantly covered by marine deposits of the Middle Miocene 'Badenian' stage.

Distinguishing and precise dating of the different marine deposits has always been a challenge. Two difficulties are the scarcity of reliable age constraints and the fact that the regional time scale is partly based on endemic fauna and regional sea level variations that cannot be compared directly to the global record. Therefore, foraminifers and nannoplankton species are being widely used for correlation to the global time scale (e.g. Hohenegger et al., 2009; Coric et al., 2009). Most Central Paratethys research is using the biostratigraphic scheme of the Atlantic Ocean to date the successions (e.g. NN-zones). The ages of these bio-events can differ over 0.5 Myrs from those in the recently revised Mediterranean biostratigraphic schemes (e.g. MNN-zones) by Laccarino et al. (2011) and Di Stefano et al. (2011).

Here, we use the Mediterranean schemes to re-date the classic Paratethys successions of the Central Paratethys basins. This alternative approach leads to the following reconstruction of the region.

The Karpatian sea stretched from the North Alpine Foreland Basin (S. Germany and Switzerland) to the Styrian and Vienna basins and was most likely connected to the Mediterranean via the Rhone Valley (Berger et al., 2005). Around 16.2 Ma the sea retreated westward. During a period of ~ 1 Myr (16.2 to 15.2 Ma) almost no marine sediments are present in the Central Paratethys, which is related to a tectonic reconfiguration termed the 'Styrian phase'. Subsequently the Badenian transgression occurred through a connection via the Transtethyan corridor in Slovenia and is related to extension in the Pannonian Basin. The sea covered Central Europe from the south (Croatian basins) to the north-west (Austrian Molasse and Vienna basins) and east (Transylvanian basin). Meanwhile, the Western Paratethys region remained continental (Fig. 1).



Fig. 1.: Paleogeography of the Paratethys Basins during the Lower Badenian (early Middle Miocene). Abbreviations for the Centra Paratethys sub-basins: GB – Getic Basin, PB – Pannonian Basin, CF – Carpathian Foredeep, STB – Styrian Basin, TB – Transylvanian Basin, VB – Vienna Basin. The Badenian sea in the Central Paratethys has no connection with the Eastern Paratethys marine domain.

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NEW MACROFLORA FROM THE UPPER MIOCENE OF THE MECSEK MTS., HUNGARY

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Macroflora from the SW part of Lake Pannon is rare: it has been known from only two localities in Hungary so far (Aranyosgadány and Pécs-Nagyárpád), one of which provided only a single leaf (Hably 2013). Numerous plant remains – mostly leaves and wood fragments, but also fruits – have been collected recently at two other sites in the Mecsek Mts., which represent two different time intervals of the Late Miocene and mean a significant addition to our knowledge on the Upper Miocene flora of the Pannonian Basin.

The older site, Pécs-Danitzpuszta, exposes the typical white marls in the lower part of the lacustrine sequence (Konrád & Sebe 2010). The dominant calcareous marls contain gray and brown clay, rarely sand and gravel interbeds and gradually get silty upwards, towards the overlying coarse sands. Plant remains were found in the uppermost, silty 3 m of the marls, where abundant molluscs indicate *Lymnocardium schedelianum* zone, i.e. an age of 11-9 Ma and sublittoral conditions (Rofrics et al. 2014). The flora contained the taxa cf. *Chara* sp., *Pinus* sp., *Glyptostrobus europaeus* (Brongniart) Unger, *Daphnogene pannonica* Kvaček & Knobloch, Lauraceae gen. et sp., *Quercus kubinyii* (Kováts ex Ettingshausen) Berger, *Myrica lignitum* (Unger) Saporta and Monocotyledonae gen. et sp. Wood fragments had previously been collected in the same stratigraphic horizon by the amateur collector László Kanizsai and had been stored in the Natural History Collection of Komló. Five of them were examined in thin sections, but due to the poor preservation they did not enable an identification more exact than 'Angiospermae (broadleaved tree)'.

This flora, which contains Laureacea species, is a markedly thermophilous one, shown by the presence of *Daphnogene pannonica* and Lauraceae gen. et sp. and the extensive swamp forest dominated by *Myrica lignitum*. *Daphnogene* so far has only been known in the Pannonian of Hungary from one borehole with a single leaf and can be considered a relict species in the Pannonian. The flora includes one of the dominant species of the Sarmatian, *Quercus kubinyii*, which indicates less wet substrate and may have survived in the elevated refugium of the Mecsek Mts. the – for this species disadvantageous – extensive paludal-lacustrine conditions created by Lake Pannon.

The younger locality, Bükkösd is an outcrop of the yellow, limonitic littoral sands typical of the upper part of Lake Pannon sediments in the region. The molluscs collected here belong to the uppermost, *Prosodacnomya* biozone of the lake, with an estimated age of 8-7 Ma (Sztanó et al in press). This site yielded abundant debris of driftwood. As sporadic freshwater bivalves (*Anodonta*) occur among the abundant brackish mollusc fauna, material transport from the dryland to the littoral zone can be supposed, suggesting a local origin for the driftwood, i.e. a provenance in the Mecsek Mts. Most wood pieces were poorly preserved, but some were investigated in thin sections. They belonged to the following taxa, including gymnosperms as well as angiosperms: cf. Coniferae, Cupressaceae *sensu lato*, *Fraxinoxylon* sp., affinity to *Fraxinus* L., and *Caryojuglandoxylon* sp.

A temperature lower than that indicated by the older flora is suggested by the disappearance of Laureacea here and in one of the coeval sites of the Mecsek (Pécs-Nagyárpád; Hably 2013) as well. Wood remains at Bükkösd indicate a mixed mesophytic forest constituted by both deciduous broadleaf and needleleaf trees. The taxon Cupressaceae refers to the presence of *Glyptostrobus europaeus*, a dominant species in swampy habitats in low-lying terrain during the younger Late Miocene but occurring only sporadically and as an accessory element in elevated areas. In spite of the dominance of floodplain species at Nagyárpád, the presence of mesophytic taxa at Bükkösd

refers to the continuing existence of an elevated refugium provided by the mountains. This is further supported by the existence of *Quercus kubinyii* at Aranyosgadány and *Fagus haidingeri* Kováts and *Quercus* sp. at Pécs-Nagyárpád.

Figures



Daphnogene pannonica, Pécs-Danitzpuszta



Fraxinoxylon sp. aff. *Fraxinus* L., Bükkösd

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BIVALVE FAUNA FROM THE SILESIAN NAPPE, POLISH CARPATHIANS: EVIDENCE FOR THE EARLY HISTORY OF THE PARATETHYS

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Strong tectonic activities around the Eocene/Oligocene boundary along the Alpine front and the collision of India and Asia created a vast inland Paratethys Sea. The first isolation of the Paratethys in early Rupelian resulted in the strong endemism expressed in uniform small-sized bivalve fauna accompanied with ostracods and nannoplankton flora represented by *Transversopontis fibula*, *T. latus* and *Reticulifenestra ornata* (Nagymarosy, Voronina, 1993). Bivalve fauna represented only by representatives of six euryhaline families is characterized by the occurrence of endemic genera such as *Merklinocardium*, *Korobkoviella*, *Urbinsia*, *Ergenica* and *Janschinella*, and endemic species of the genera *Cerastoderma*, *Lenticorbula* and *Congerina*, able to adapt to changes in salinity. This paleoenvironmentally significant bivalve fauna was described from the Solenovian deposits of the Eastern Paratethys (Voronina, Popov, 1985). It was also noted from the middle Kiscellian of Hungary (Báldi, 1986) and Transylvania (Rusu, 1988).

Prior to our study bivalve associations typical for Solenovian were known from the Outer Carpathians only at Křepice, Moravia in Czech Republic and at Piatra Neamț, Romania.

The two bivalve species viz., *Korobkoviella* cf. *lipoldii* (Rolle) and ?*Lenticorbula* sp. were recognized in Křepice (Čtyroký, 1991). According to Rusu (1999) Romanian fauna consists of *Cerastoderma serogosicum* (Nossovsky), *Korobkoviella lipoldii* (Rolle), *Urbinsia lata Gontsharova*, *Polymesoda convexa* (Brogniart), *Lenticorbula sokolovi* (Karlov) and *Janschinella garetzkii* (Merklin).

The most recent field work undertaken in the Silesian Nappe has resulted in an intriguing new bivalve fauna recovered at Jabłonica Polska near Krosno. Sixteen bivalve species have been identified within material gathered from the Dynów Marls the origin of which is connected with submarine debris flows (Studencka et al., 2009). Six bivalves: *Korobkoviella* cf. *kiktenkoi* (Merklin), *Korobkoviella* cf. *ahalcichensis* Popov, *Lenticorbula slussarevi* (Merklin), *Lenticorbula mefferti* (Titova), *Lentidium* cf. *ianischewskii* (Ruchin) and *Lentidium* cf. *ustjurtense* (Merklin) have previously been known only from Solenovian. Five other species: *Cerastoderma serogosicum* (Nossovsky), *Lenticorbula sokolovi* (Karlov), *Lentidium ustjurtense* Merklin, *Janschinella vinogradskii* (Merklin) and *Congerina (Mytilopsis) kochi* Andrussov have been reported from both Solenovian and middle Kiscellian. The present research provides the first occurrence of *Lenticorbula mefferti* (Titova) and *Lenticorbula slussarevi* (Merklin) in the Carpathian Basin. The bivalve fauna from Jabłonica Polska is the richest assemblage in the Outer Carpathians and one of the most diversified in the whole Paratethys Province. The only more diversified Solenovian bivalve assemblage is found in Akhalcikhe, Georgia. Contrary to bivalve shells from Jabłonica Polska, generally unfavorably preserved, those from Akhalcikhe are excellently preserved.

The newly collected material, first of this kind in Poland and third in the Outer Carpathians (Čtyroký, 1991; Rusu, 1999), is of great importance for correlation of the Carpathians flysch with the Kiscellian deposits of Hungary and in Transylvania, Romania. It also shows that around the NP 22/NP 23 nannozone boundary, peculiar bivalve fauna populated both the Carpathians (Čtyroký, 1991; Rusu, 1999; and our study) and the Pannonian Basin (Báldi, 1986; Rusu, 1988); it was also typical for the Solenovian of Ukraine, Russia, Georgia and Kazakhstan. This peculiar fauna represents the first real Paratethyan endemic macrofaunal zone and indicates conditions of an inland sea extending from Bavaria to Transcaspia (Voronina, Popov, 1985) with pliohaline (salinity less than 20‰) water oxygenated at the surface and euxinic environmental conditions at the bottom.

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NEW CONSTRAINTS IN THE UPPER MIOCENE AND PLIOCENE STRATIGRAPHY OF THE DANUBE BASIN BASED ON APPLICATION OF THE AUTHIGENIC $^{10}\text{Be}/^9\text{Be}$ DATING METHOD

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Efforts to reconstruct the Late Miocene evolution of the Pannonian Basin System are constantly challenged by lack of sufficient geochronology data. Recently it was demonstrated, that authigenic $^{10}\text{Be}/^9\text{Be}$ dating method could be applied to date continental deposits to 8 Ma and its applicability is expected up to 14 Ma (Lebatard et al., 2010). This study presents the first application of the authigenic $^{10}\text{Be}/^9\text{Be}$ dating method in the Lake Pannon realm, examining its high potential to resolve the basin history. As a study area was chosen its northern margin - the Danube Basin, where the objects of dating were lacustrine, deltaic and alluvial sequences.

The method is based on measurement of the natural ratio of beryllium-10 / beryllium-9. ^{10}Be is a cosmogenic nuclide produced in atmosphere and is transported to sedimentary environment by precipitation, while ^9Be is provided by weathered rocks of the orogen massifs and transported by rivers. In water column both isotopes are mixed then adsorb to surface of clay minerals and after deposition their ratio is only function of the ^{10}Be decay and follow the radioactive decay law $N = N_0 \cdot e^{-\lambda T}$, where N and N_0 are the $^{10}\text{Be}/^9\text{Be}$ ratios measured in the samples and the initial ratio respectively, λ is the radioactive constant of ^{10}Be ($T_{1/2} = 1.387 \pm 0.01$ Ma (Chmeleff et al., 2010), $\lambda = \ln(2)/T_{1/2}$) and T the time of deposition. After determination of the local initial ratio from $^{10}\text{Be}/^9\text{Be}$ measurements in the Holocene sediments, the time of deposition can be determined through the $^{10}\text{Be}/^9\text{Be}$ measurement in unknown samples. Two N_0 values were inferred for lacustrine and floodplain sedimentary environments.

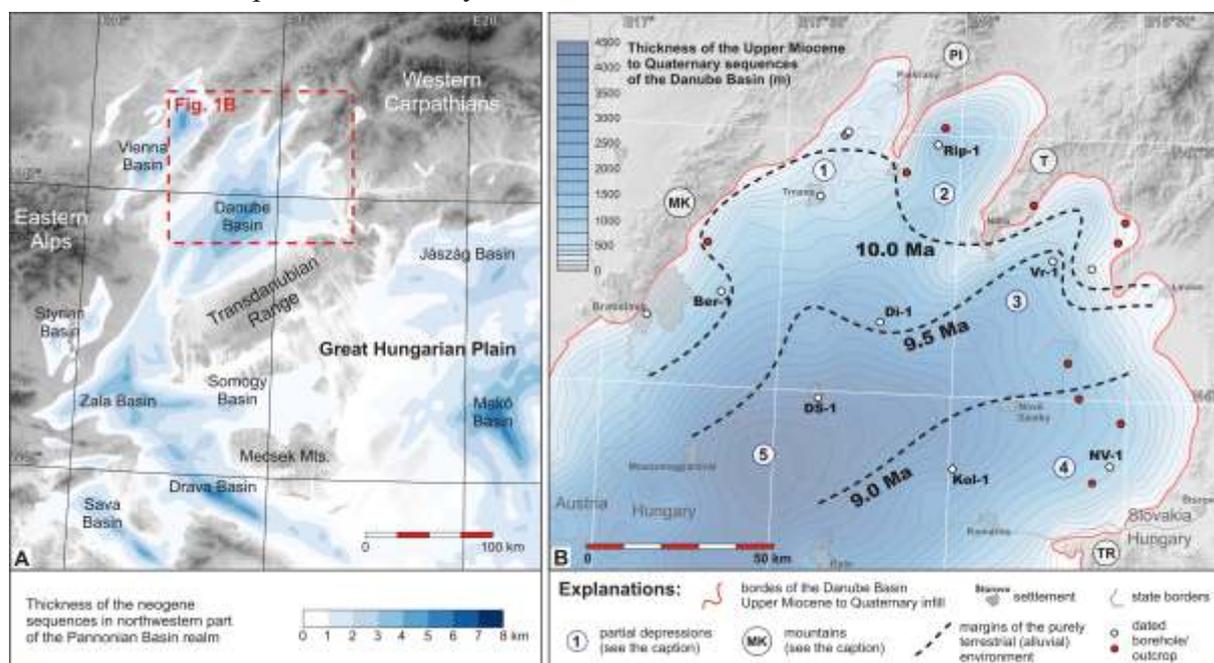


Fig.1.: A: Location of the study area - northern Danube Basin; B: Study area with lines of subsequent regression according to dating results. Partial depressions: 1 - Blatné d., 2 - Rišňovce d., 3 - Komjatice d., 4 - Želiezovce d., 5 - Gabčíkovo d.; Mountains - MK - Malé Karpaty, PI - Považský Inovec, T - Tribeč, TR - Transdanubian Range.

Sedimentary sequences were defined mainly from well-logs and well cores, with respect to seismic stratigraphy results by Kováč et al. (2011), and taking into account surficial occurrences of sedimentary formations. Late Miocene succession is composed by: (1) the Ivanka Formation comprising deepwater deposits (mainly turbidites), shelf slope succession and shelfal strata;

(2) the Beladice Formation consisting deltaic deposits; (3) the Volkovce Formation representing alluvial sequence. In minor part were studied also Pliocene braided river sediments of the Kolárovo Formation and Quaternary alluvial deposits.

Resulting ages are in good accordance with existing biochronological data, which are based mainly on mollusc and mammal biozones. While time span of these biozones is often too wide, the obtained radiometric data provides refined timing with implications for development of depositional systems in the Danube Basin. New ages are in agreement with timing of progradation of the shelf slope margins defined by Magyar et al. (2013).

Main interpretations of the dating results for the basin development could be stated as follows: (1) lacustrine succession (Ivanka Fm.) was accumulated in time span 11.6 - 9.0 Ma, in agreement with Kováč et al. (2011); (2) deltaic succession (Beladice Fm.) is proved to be highly diachronous. Deltaic environment firstly appeared in the Rišňovce depression (well Rip-1) at ~11.0 Ma, while the deltaic environment in the southern basin margin (Želiezovce depression, well NV-1) is documented first at ~9.5 Ma; (3) overall regression and sedimentation in alluvial environment (Volkovce Fm.) was connected with progradation of the deltaic environment and was also diachronous, with beginning at ca 10.5 Ma on the basin northern margin up to 8.7 Ma on the southern margin; (4) alluvial sedimentation continued in prevailing meandering river environment up to 6.0 - 5.0 Ma, when the basin inversion started; (5) sedimentation of a braided river system (Kolárovo Fm.) of the Pliocene age lasted in the Blatné depression up to 2.6 Ma.

The present study confirms the high potential of the authigenic $^{10}\text{Be}/^9\text{Be}$ dating method in the Alpine - Carpathian - Pannonian realm and documents that reliable results could be obtained up to 12.0 Ma from lacustrine as well as from alluvial strata.

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RIVERS, DELTAS, TURBIDITE SYSTEMS: AN OVERVIEW OF SEDIMENTATION IN LAKE PANNON

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Lake Pannon was a large brackish water body in the Pannonian Basin during the Late Miocene to Pliocene. It was a mosaic of mostly elongated troughs and elevated highs developed during Early to Middle Miocene rifting. In Late Miocene long-term thermal subsidence led to the formation and maintenance of deep basins, some hosting 6000 m thick sediments until now. Sediments were shed from the Alps and Carpathians via fluvial to deltaic feeder systems and normal regression lasted for about 6 Ma (Magyar et al., 2013). A wide morphological shelf developed with inner-shelf to shelf-edge deltas, transiting repeatedly due to recurring floodings. Variations in accommodation, an interplay of subsidence and climatically driven lake-level changes, were reflected by deltaic successions, which accumulated up to 1000 m thickness locally (Juhász et al., 2007). Development of accommodation also controlled evolution of the basin-margin slope and the turbidite systems in the basin interiors. During the long history of the lake three different type of turbidite systems evolved: the oldests were locally fed, the majority got sediment from the remote sources. Depending on the basin floor relief these latter were either confined or unconfined.

A large number of hydrocarbon accumulations were reported from both the deltaic and turbidite successions (Horváth & Tari, 1999), therefore hundreds of wells and cores were studied. Industrial 2D and 3D seismic volumes helps to visualize the evolution of the basin-margin slope and the basin fill architecture. The architecture of delta lobes were revealed by high and ultra-high resolution seismic images (Horváth et al., 2010). Fluvial and deltaic deposits also crop out due to Pliocene to Quaternary basin inversion.

Rivers which run towards the lake were mostly meandering. But several examples of anastomosing rivers were detected both in outcrops and on seismic images. As the overall relief might have been very flat anastomosing remained a common pattern not only on delta plains, but on alluvial plains locally. Geometries, dimensions of channel-fill sand bodies (100's m vs. few 1000's meters width) and connectedness might significantly differ, influencing their reservoir potential in shallow biogenic gas plays.

Deltaic lobes are extremely complex bodies. They are made up of 2-8 m thick cyclic repetitions of marls, silts, sands, organic-rich clays or thin lignite seams, commonly cut by channel-formed cross-stratified sand bodies. The fauna faithfully reflects the patchy environmental conditions, and encompasses a wide spectrum of ecological groups, from brackish littoral through freshwater and terrestrial molluscs. The successions represent lacustrine parasequences, shallowing up units deposited as interdistributary bay fills, delta-plain marshes and distributary channel fills. Their variation mostly follows autocyclic environmental changes. These parasequences comprise 20-50 m thick coarsening upwards units, which are interpreted as delta lobes. High resolution seismic proved that boundaries of delta clinoform packages do not necessarily mark major flooding events, but may develop as onlaps of coeval lobes. The long-term cyclicity and stacking of coarsening up delta bodies, however, reveal climate-driven variations of base level (Sztanó et al., 2013a).

Lacustrine base level, reflected by shelf margin trajectories, rose continuously, though at varying rates parallel with advance of the shelf-slope (Sztanó et al., 2013b). When deltaic lobes prograded on the shelf, the trajectory was ascending, several 100 meters high basin margin clinoforms developed in an aggradational pattern. At the same time sand was partitioned between the shelf and the basin. A huge portion of the sand was transported by effective turbidity currents through leveed channels into the basin. These sands deposited either as thick, extended slope-detached turbidite lobes up to a distance of 30-50 km from the shelf edge, or depending on the basin floor relief they reached the deepest ultimate sinks where they became confined.

In this position sandy turbidites, in form of small lobes covered rapidly the basin floor, and in the following period basin-centered turbidite systems made up of stacked lobe complexes accumulated up to a thickness of 1000 m in these deep troughs. Direction of channels and a variety of turbidites including hybrid event beds reveal that these deep troughs acted as confined basins. Regionally extended marker shales indicate that deposition ceased only when the shelf got flooded and the feeding delta systems stepped back several 10's of kms. As these deep basins got gradually filled up by turbidite sands, the topographic differences got mostly eliminated and finally confinement ended. Turbidity currents either built extended slope-detached turbidite lobes near the basin-margin slope or continued transport to the next depression.

When lacustrine base level was stagnant the shelf got bypassed, sediments accumulated on the slope and at the slope-toe as small simple lobes. Short-distance transport was the result of clay-poor, non-effective turbidity currents and slumps. Consequently, the thickness of coeval basin-centre sediments remained negligible. The corresponding geometry of the basin slope is progradational, drawn by flat shelf margin trajectories. Aggradational and progradational shelf-slope cycles are fourth-order sequences, repeated in 100 kyr time intervals.

Descending trajectories were not observed, therefore base-level drops larger in amplitude than the seismic resolution (20–30 m), did not occur between 9–5 Ma ago, including the period of the Messinian salinity crisis (Magyar & Sztanó, 2008).

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MIDDLE MIOCENE EVAPORATES FROM BOREHOLE SUCCESSIONS IN HUNGARY

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In the last decades some of the thousands of boreholes, drilled in Hungary, penetrated Middle Miocene evaporates belonging to the Budajenő Formation [Jámbor 1975, unpublished well report=UWR (1)]. Authors give a short summary of the occurrences (Figure 1) known so far.

In the Little Hungarian Plain (W Hungary) evaporates are known only from the continuously cored well Nagylózs-1. Thin gypsum and dolomitic sandstone beds were exposed in section 1198.7–1201.4 m [Don, Zsámbok, UWR (1)], and their age is ca. 13.8–13.9 Ma (Selmeczi et al. 2012). Boreholes Mány-17, -22 and Perbál-5 in the Zsámbék Basin transected complete Sarmatian successions. Based on foraminifera studies by Görög (1992) the warm and shallow lagoon became hypersaline from time to time during the Upper Sarmatian *Spirolina austriaca* Zone, as it is indicated by pathologic foraminiferal shells. Lithological descriptions mention no evaporates. Based on the presence of oolitic limestones, hypersaline facies was assumed by Jámbor (1978) over the entire Sarmatian age. Continuously cored well Budajenő (Bó)-2 penetrated Middle

Badenian–Lower Sarmatian succession (249.9–374.5 m) comprising the alternating beds of gypsum, anhydrite, native sulphur and organic matter-rich clay. This section is the stratotype of the Budajenő Formation [Jámbor 1975, UWR (1)].

In SE Transdanubia, in the area of the SW–NE stretching basin from South Zala towards the Zagyva (Haas ed. 2012), a 70-cm-thick anhydrite succession comprising clay laminae — considered as Sarmatian — was mentioned from borehole Tengelic (Te)-1 by Hönig [1970, UWR (1)]. Well Zomba-1 also transected evaporate deposits [Nusszer et al. 2002, UWR (2)]. Drill chips and core samples from section 1018–1104 m contained evaporate layers of different thicknesses (from lamina to 1–2 m). Based on fossils their age proved to be Sarmatian–Badenian.

NE of the previous area in the basin (Haas ed. 2012), well Ráckeve-1 exposed the Budajenő Formation in a thickness of almost 300 m (1802–2080? m, drill chips) under the thin Sarmatian succession [Cserepesné et al. 2004, UWR (2)]. Based on sporomorphs and foraminifers it belongs to the Agglutinated Foraminifera Zone of the Middle Badenian. The Budajenő Formation was identified in section 2905–3600? m within the ca. 1000 m-thick microfossil-rich Badenian succession in well Ráckeve-Ny-1 [Cserepesné et al. 2013, UWR (2)]. Under and above the “highest-salinity” beds (3200–3450 m) sediments of anoxic facies were found; they are rich in organic matter and comprise calciphores and a poor foraminifera assemblage. Budajenő Formation interfingers with the Lajta Limestone (“Leithakalk”) and Szilágy Clay Marl Formations within short intervals. Its age is considered to be Middle–Late Badenian. In well Valkó-1 [Cserepesné et al. 2000, UWR (2)] anhydrite beds (1152–1205 m, drill chips) were formed in the Badenian according to the poor foraminifera fauna.

The continuously cored well Szirák-2 was drilled in the western foreland of the Zagyva Trough. Gypsum and anhydrite beds described from the succession (1109.5–1270 m) are considered to be of Early Sarmatian age on the basis of fossils (Hámor 1992).

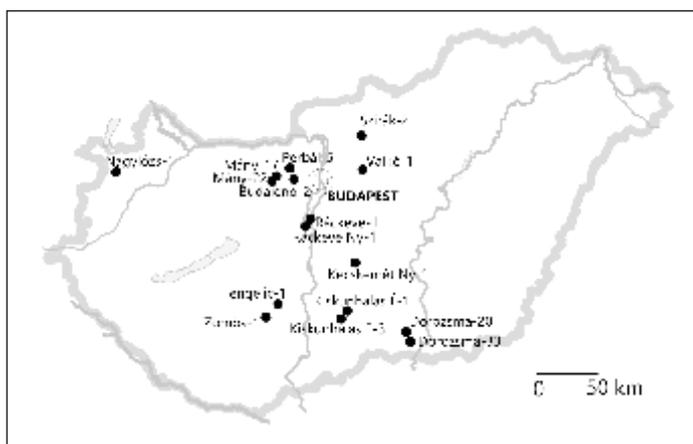


Fig. 1.: Location of wells transecting evaporate deposits, referred to in the text.

Evaporate–anhydrite-bearing beds are also present in discontinuously cored wells drilled in the Kiskunság area (Danube–Tisza Interfluve). Well Kecskemét (Kecs) Ny–1 transected thin anhydritic clay marl of Badenian age [2125–2127 m, low core recovery, age based on the poor foraminifera fauna, Szepesházy et al. 1964, UWR (2)]. From well Dorozsma (Do)–20 a ca. 0.5 m anhydrite interbedding is known; its Sarmatian age is proved by the poor foraminifera fauna. In drill chip samples of Badenian age from well Dorozsma (Do)–33 gypsum and anhydrite crystals were found [3012–3020 m, Nusszer et al. 1984, UWR (2)]. In the area of the Soltvadkert sub-basin, in borehole Kiskunhalas (Kiha) É–1, anhydrite was transected between two clay marl beds (sample is derived from 2354.5–2360 m). Fossil data are available only from the underlying clay marl: it yielded rich Badenian foraminifera assemblage [Cserepesné et al. 1983, UWR (2)]. The 2518–2521.5 m sample (black, compact dolomarl comprising anhydrite crystals in bands) in Kiskunhalas Kiha É–3 yielded no evaluable fossils. The core sample — taken from the overlying succession (2380–2385 m) — yielded Sarmatian fossils [det. Kőváry in Cserepesné et al. 1985, UWR (2)]. The RAG Kiha Ltd. also drilled a well in the area; it transected evaporate deposits belonging to the Budajenő Formation in a thickness of 70 m.

Based on our studies the greater part of the Middle Miocene evaporates in Hungary were formed in the younger period of the Badenian and some of them approximately coincide with the Badenian Salinity Crisis (e.g. Peryt 2006, Harzhauser, Piller 2007, Leeuw et al. 2010). For lack of adequate data (due to discontinuously cored successions, scarce fossil record etc.) the deposition of some Badenian evaporate occurrences (e.g. Kecskemét, Dorozsma, Kiskunhalas, Valkó), cannot unambiguously be correlated with this event. Evaporate sedimentation in the Zsámbék Basin of unique evolution started in the Middle Badenian (Budajenő–2) and — as it is indicated by the foraminifers — nearly hypersaline conditions persisted even in the Late Sarmatian but without evaporate formation (Görög 1992). Evaporate formation took place also in the Sarmatian in Szirák–2 and Tengelic–1 successions. Deposits of the Budajenő Formation known so far from boreholes in Hungary reach their maximum thickness in the area of the a South Zala–North Somogy–Mecsek–Kiskunhalas–Zagyva–Hernád Trough (Haas ed. 2012): Ráckeve–Ny–1: ca. 700 m, Ráckeve–1: ca. 300 m. The thickness of evaporates formed in lagoons along basin margins ranges between a few cm to 100–200 m (Szirák–2, Zomba–1).

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CONFINED TURBIDITE BASINS IN THE LAKE PANNON – EXAMPLES FROM SOUTHWESTERN HUNGARY

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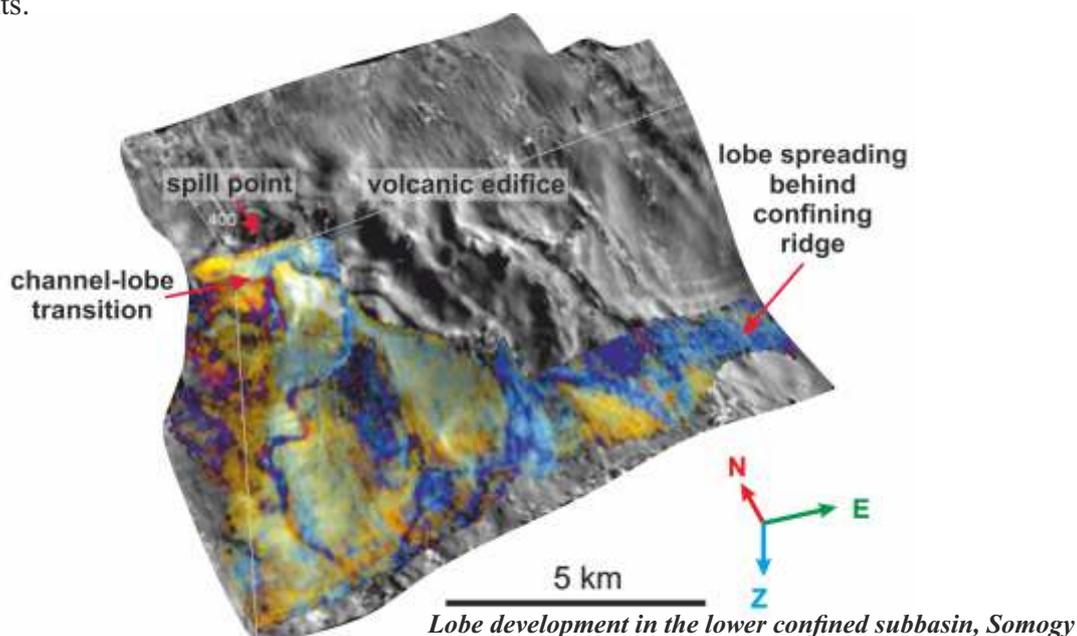
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Uneven basin topography significantly alters the route of turbidity currents and the depositional architecture of turbidite systems. Confined basins can develop in a wide range of tectonic settings. The basement of the Pannonian Basin was highly irregular due to normal and strike-slip faulting during synrift extension in the Early to Middle Miocene, minor inversion around the turn of Mid/Late Miocene and recurrence of fault activity during the early Late Miocene. Lake Pannon inundated the relief in the Late Miocene, and even 600 to 1000 metres deep depressions were present. Profundal marls covered unevenly the floor of the deep regions as well as that of sublacustrine highs.

Selected 3D seismic datasets were interpreted and the decompacted thickness of the main sedimentary packages was calculated to reveal the syndepositional palaeotopography. Spectral decomposition was used to map geomorphological architectural elements. Well logs and core studies aided in constraining the stratigraphy and the evolution of deep-water architectural elements.



Two scales of confining topography can be identified. The higher irregularities are in the scale of depressions: they are 10s of kilometres in length, several 100s of metres in depth and are mainly related to the overall structural setting. The smaller ones are in the range of several kilometres in length and 100 metres in depth. The latter have different origins: reactivation of Cretaceous nappes (Drava Basin) or Middle Miocene volcanic edifices (Somogy area) played a role in shaping the topography. This smaller scale confinement can be traced well on 3D seismic volumes. The direction of slope progradation is a major factor in the routing of turbidity currents. Where slope-parallel confining ridges exist, sediment spills into the lower subbasin at one spill point. The development of sheets with continuous seismic facies onlapping basement highs suggests that the lower subbasin was confined. Later on, a well-defined lobe with the channel-lobe transition at the spill point developed. Channels cutting through the lobe may be the result of progradation of the system. As the lower subbasin filled and the base level rose, sediment was trapped in the upper basin,

with compensationally stacked lobes. In the next phase of development, channels were still diverted from the covered range but found their way to the then levelled out lower basin. The smaller scale of confining topography was greatly reduced by the time the slope progradation reached the area, but the larger scale of topography still affected slope development.

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THE SARMATIAN STAGE IN HUNGARY

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The Sarmatian Stage in Hungary is generally thin but displays considerable lithological variety. The best-studied sections comprise 40-60 m thick shallow-water limestone bodies formed in 3-5 km wide, rimmed carbonate platforms along basin margins. A single sedimentary unit consists of steeply dipping slope deposits (grainstone/packstone), heavily moved lime sand bars (grainstone), horizontal lagoonal deposits (packstone/wackestone), abrasional limestone boulders and coastal dunes (grainstone). The distribution of texture types is in good correlation with the Sarmatian coastline. Prograding ooid deposits with abundant serpulid–microbial–bryozoan–nubeculariid buildups also occur in lagoonal settings. All these carbonates were deposited mainly above fair weather wave base and partly between fair weather and storm wave base, at about 20–25 m water depth. The calcareous sand was transported by wave action, coastal currents, and frequent storms. During lowstands, part of the carbonate sand was moved by wind towards the dry land and formed coastal dunes. The abrasional limestone boulders were probably transported towards the basin by tsunamis (Palotás 2014). Other types of shallow-water sediments include coarse clastics deposited in rocky shores and Gilbert-type deltas, and shallow-water evaporites, such as anhydrite, gypsum, and sulphur, precipitated in small, semi-isolated basins.

The offshore sediments, connected to the shallow-water ones along a very narrow transition zone, comprise grey to greenish-grey mollusc-bearing clays, clayey marls, and calcareous marls. Laminites with fish skeletons and high organic content were deposited in dysoxic or anoxic offshore environments.

As to stratigraphy, the Sarmatian is usually bounded by an unconformity both at its base (towards the Badenian) and its top (towards the Pannonian), but continuous sedimentation was also assumed in some restricted areas. The Sarmatian is divided into two zones by molluscs, three zones by foraminiferas (*Elphidium reginum*, *Elphidium hauerinum*, *Spirolina austriaca* zones), and two zones by ostracods (*Cytheridea hungarica*-*Aurila mehesi* and *Aurila notata* zones) (Boda 1974; Görög 1992, Tóth 2009).

The boundary of the lower and upper Sarmatian sequences is clearly distinguished and well correlated, but the Upper Sarmatian beds could only be divided ecostratigraphically based on the microfauna. The appearance and abundance of the index fossils as *Elphidium hauerinum* (d'Orbigny), *Porosonion granosum* (d'Orbigny) and *Spirolina austriaca* d'Orbigny depend strongly on the facies (Tóth 2009).

The palaeoecological interpretations of the microfauna and the geochemical data suggest shallow, stable warm-temperate bottom water temperatures (~15°C), well ventilated, mainly brackish seawater (littoral zone, maximum 80 m deep) with rich algae and/or seagrass vegetation on the bottom and periodic phytoplankton blooms during the Early Sarmatian (*Elphidium reginum* Zone). The faunal changes observed in the *Elphidium hauerinum* Zone can be explained by a sea-level highstand with dysoxic conditions. A relative sea-level fall with a maximum depth of about 50 m, and well ventilated, warm-temperate and more brackish (17-23‰) conditions are documented in the uppermost part of this zone. In the overlying *Spirolina austriaca* Zone, the microfauna indicates warm (15-21°C), well-ventilated, close to normal marine shallow lagoon and marsh environments with high fluctuations in salinity (15-43‰) (Cornée et al. 2009; Tóth & Görög 2008; Tóth et al. 2010).

The Sarmatian of the central Pannonian basin (Hungary) significantly differs from the Sarmatian successions of the peripheral basins, such as the Vienna, Kisalföld/Danube, East Slovakian, Transylvanian basins etc., in 1) being very thin (less than 100 m in the Alföld / „Great Hungarian Plain”/ area); 2) generally lacking the otherwise widely distributed lowest Sarmatian *Anomalinoidea dividens* Zone, probably as a consequence of ecological factors (water depth?) rather than a real stratigraphic hiatus; and 3) being represented mostly with shallow-water deposits. All these differences suggest that much less accommodation space was available during the Sarmatian in the central Pannonian basin than in its peripheral basins. This feature indicates the effects of lithosphere-scale processes, possibly a mantle upwelling.

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PROGRADATION OF LATE MIOCENE DELTA CLINOFORMS IN THE SOUTHERN FORELAND OF THE TRANSDANUBIAN CENTRAL RANGE

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The Transdanubian Central Range (TCR) was a peninsula in the large Lake Pannon and was gradually flooded at about 10 to 9 Ma ago (Magyar et al., 1999; Csillag et al., 2010). At that time the southern foreland of the TCR might have been covered by relatively shallow lacustrine waters (<100 m deep). After the rapid infill of the Danube basin normal regression continued, and rivers coming from the N, NW had built a quite uniform delta plain in the area approx. 9 to 8 Ma ago (Sztanó et al., 2013).

Systematic high-resolution seismic surveys at Lake Balaton offered images on fine scale geometry, particularly progradational pattern of deltaic lobes of various size. Clinoform strata comprise several stacked deltaic cycles due to repeated phases of transgression. Although each flooding affected the whole area, the deposition was different in the western and eastern parts because of differences in initial paleo-water depth.

To the east an elevated basement plateau was situated, which could have remained a dry land when the western area was inundated by several tens of meters deep water. The bays along the western margin of this elevated block were bypassed and filled up by delta lobes mostly arrived from N-NE direction. This delta gradually turned to the West and created a North-South striking front. At the same time, a delta complex arriving primarily from the direction of the Tapolca – Sümeg Trough was built to an easterly direction into the much deeper (50-70 m) western basin. The two delta systems met east of the present Tihany Peninsula (Horváth et al., 2010). A minor relative lake level rise resulted in the abandonment of the eastern system and flooding of the elevated basement block to the East. Finally the progradation of the western delta became dominant, and created a quite flat and uniform topography. Subsequent transgressional events resulted in additional delta cycles (<30 m), which were also characterized by deposition of easterly heading delta lobes. Younger cycles contain more and more channels and point to a gradual change in landscape from delta to alluvial plain.

Interpretation of high-resolution seismic sections led to the recognition of an intricate system of oblique delta progradation as opposed to the general NW-SE trend determined by shelf-slope constructions (e.g., Törő et al. 2012, among others). A possible explanation for this unexpected progradational directions is that TCR was an obstacle for sediment transport regardless its water coverage. Sediment transport preferably followed low lying gateways such as the Tapolca – Sümeg Trough and an unknown location N-NE of the Siófok basin. The majority of the sediment flux evaded the local highs. As a result the delta plain has extended laterally to a direction almost perpendicular to the main sediment transport and filled accommodation behind the barrier before prograding further to the SE.

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A COMPREHENSIVE REVIEW OF THE MIDDLE MIOCENE IN THE MARGINAL PART OF THE CARPATHIAN FOREDEEP BASIN (POLAND AND UKRAINE)

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Miocene deposits in the northern and eastern margins of the Carpathian Foredeep Basin (CFB), spreading widely from Czech Republic, through Poland to Ukraine and Moldova as far as to Romania, yield a wide range of variable lithofacies. They consist of normal marine Badenian and restricted semi-marine Sarmatian deposits that are characterized by diversified sets of sedimentological and biogenic structures ascribed mainly to the shallow-water environment. They are well exposed in three main regions in the northern margin of the CFB: Roztocze Hills (PL-UA cross-border), Opole Minor (between Lviv and Mykolaiv, UA), and the Medobory Hills (between Ternopil and Kamianets Podilskyi, UA).

Generally, the Miocene succession of the Roztocze Hills begins with transgressive quartz sands and sandstones of Early Badenian age, with their greatest thicknesses and limits in the Ukraine. Towards the top, the sands pass laterally into marls and red algal limestones. The latter deposits are overlain by a continuous level of gypsum and/or Ratyn Limestones (both included into Tyras Suite). Various shallow-water carbonate and terrigenous deposits of Late Badenian age overlie the evaporite strata, both in Poland and Ukraine. The terrigenous rocks are represented mainly by quartz sands and sandstones with an admixture of glauconite, siltstone and clay. The biogenic rocks are represented by various shell coquinas and reefal-type deposits. The Miocene succession of the Roztocze Hills is terminated by deposits of Sarmatian age. These are represented by serpulid-vermetid reefs and serpulid-microbial build-ups, exposed in the westernmost part of the Roztocze Hills.

The most typical lithofacies for the Opole Minor area are the Lower Badenian Mykolaiv Sands that spread out upon adjacent regions of Opole, to cover an area of about 1.300 square kilometres. The variable sedimentary depositional structures, and ubiquitous burrows, evidence their development as a complex stack, several dozen metres thick, of sand shoals or bodies of various kinds, some of which were temporarily raised up to sea level. Amidst the shoals, the storm scourings have intermittently formed channel-like infills, some of them with residual lags at the base. The reversed density stratification and/or an increasing gravity gradient have involved mass deformations or movements, some of which are suggested to be triggered by seismic shocks focused at the shore or the adjacent hinterland of Podolia and Volhynia. Diverse, locally mass-aggregated fossils typify particular sand sets/bodies to form allochthonous assemblages, some members of which (*cirripedes Scalpellum* and *Creusia*, sharks *Hemipristis*, rays *Myliobatis*) are new for the Ukrainian part of the CFB. Other assemblages considerably enrich the faunal content of all Middle Miocene (Badenian), either in terms of taxonomic diversity, or eco-taphonomy of selected taxa (starfish *Astropecten*, diverse echinoids).

The whole faunal world of the Mykolaiv Sands is recognized to accentuate its profuse development during the global Middle Miocene Climatic Optimum at Early Badenian times.

The most prominent components of the Upper Badenian are coralline algal reefs constructed mainly by crustose coralline algae that form the Medobory Hills well exhumed in recent morphology. The presence of corals as well as other warm-water taxa suggests that the Upper Badenian Medobory reefs have originated in slightly warmer waters than the contemporaneous, very similar coralline algal-vermetid reefs from the Roztocze Hills. The reefal-type deposits are associated with a variety of bioclastic, marly and rhodoid facies.

They are covered by the Lower Sarmatian serpulid-microbialite reefs, which are located at the SW foot of the Medobory Hills where they build rocky hills called the “toutra” mounds. The “toutra” mounds are usually arranged in linear rows that are more or less perpendicular to the Medobory Hills.

The bryozoans, another good indicator for the fossil facies, are well-differentiated through the Lower Sarmatian (Volhynian) carbonate buildups. They show different assemblages in the spatial distribution, taxonomical content and the colony growth-pattern, which depend on the facies characters such as reefs, marly and silty facies as well as organodetrital (fine-grained) calcareous sands in the NE margin of the CFB.

SEDIMENTARY MODEL OF LOM COAL BASIN, NW BULGARIA

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Lom coal basin is located in NW Bulgaria in the west subsided part of the Lom Depression (Fig. 1) which represents a part of the Lom bay of the Dacian Basin (Kojumdgieva, Popov, 1988). Our previous studies (Yaneva et al., 2010; Yaneva, Ognyanova-Rumenova, 2010, Yaneva, Ognyanova-Rumenova, 2012) dealt with the sedimentary characteristics, diatom content and stratigraphy of the coal-bearing formation, and confirmed the existing opinion (Siskov, Angelov, 1984) about freshwater fluvial-lacustrine environment with good aeration and relatively high hydrodynamics.

The Neogene sedimentary fill of the basin comprises alluvial sand, silt and clay, interbedded with coal beds. Neogene sediments are covered by loess deposits of Quaternary age. The Neogene sediments in Lom coal basin are assigned to the following formal lithostratigraphic units – Smirnenki Formation, Archar Formation and Brusartsi Formation (Kojumdgieva, Popov, 1988). Our study is focussed on the last one, which is coal-bearing. The sedimentary model is based on sedimentological and palaeontological data from 21 boreholes and digital model of the palaeorelief, based on more than 200 boreholes.

Sediments of the Brusartsi Formation are of mixed type – sand, silty sands, clayey and silty sands, sandy silts, silty clays, diatomaceous clays, and clays. In the lowermost parts thick lignite coal beds, interbedded by clays and clays with plant detrite, and rarely by sands are described. In the upper parts, in some boreholes sand is enriched in gravels. Calculated grain-size statistical parameters (mean, standard deviation and skewness) characterised these sediments mainly as river sands (Boggs, 2009).

According to their mineral composition, sands are defined as arkose wackes and arenites. Quartz is the dominant rock-forming mineral, followed by feldspars and rock fragments; accessory minerals are mica, hornblende, titanite, epidote, garnet, chlorite, etc. Fine grained sediments as clays and silts are composed dominantly of clay minerals from smectite group, mixed-layered smectite-kaolinite and illite-muscovite, quartz, plagioclase and less potassium feldspars.

Massive regression, which started during Maeotian, continued during Pontian and Dacian. Dacian basin is shrinking and shallowing, thus drowned valleys emerged at the surface and favored formation of alluvial-deltaic plain with fluvial sedimentation regime. Shallow freshwater lakes and swamps was formed. The results of the diatom analysis led to the following paleoecological conclusion about the environment during the formation of sediments: a) eutrophic freshwater lake with quickly changeable depth and inflow of river water; b) variable active reaction of the water – from neutral to slightly alkaline, often changing in acid; c) temperature regime - similar to those in lakes in temperate latitudes.

Results after diatom analysis show that peat swamps were of eutrophic type. The coal beds are of lens-like lateral distribution, alternating with clays and sands. At some places wash-outs are described on the upper bed surface of coal, followed by sandy deposits with peat fragments. These intra-formational washouts evidenced fluctuation of the alluvial condition during the time. The digital model of the delta plain palaeorelief shows that the main canal direction is from south to the north with two subordinate canals to the NE and NW.

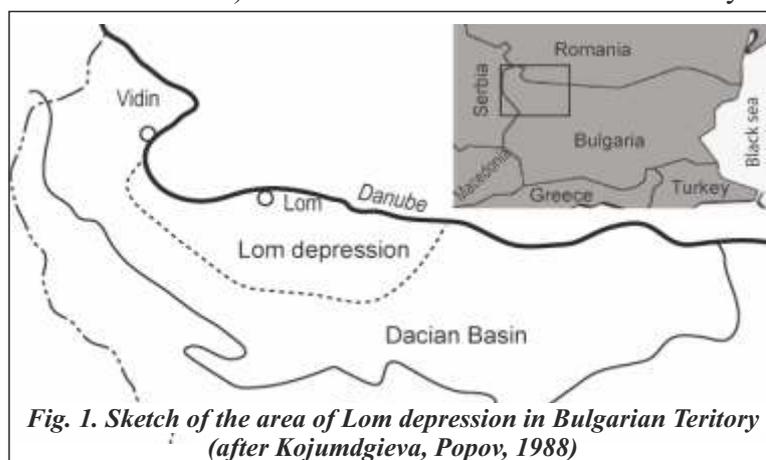


Fig. 1. Sketch of the area of Lom depression in Bulgarian Territory (after Kojumdgieva, Popov, 1988)

Results after diatom analysis show that peat swamps were of eutrophic type. The coal beds are of lens-like lateral distribution, alternating with clays and sands. At some places wash-outs are described on the upper bed surface of coal, followed by sandy deposits with peat fragments. These intra-formational washouts evidenced fluctuation of the alluvial condition during the time. The digital model of the delta plain palaeorelief shows that the main canal direction is from south to the north with two subordinate canals to the NE and NW.

The active tectonic regime and the massive regression led to the formation of a wide delta plain by moving the delta front to the North. In this direction the basin was gradually filled in with sediments and coal-bearing levels in the North are increasingly younger. The lowermost coal beds at Romanian territory, about 20 km north of the town of Lom, are of analogous age as the uppermost coal beds in the Lom basin. While in the area of Lom basin coal formation completed during the Late Pontian, according to data from diatom analysis (Yaneva, Ognjanova-Rumenova, 2012), according to Romanian authors coal formation in the region of the town of Oltenia has proceeded during the Late Dacian and to the Middle of Romanian age (Pana, et al., 1981; Enciu, 2009).

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Neogene stratigraphy in the Mecsek region

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NEOGENE STRATIGRAPHY IN THE MECSEK REGION

Neogene sediments in Hungary accumulated in the Pannonian Basin, the largest basin of the Central Paratethys. The Early to Middle Miocene period (up to the Badenian) is the time of active lithosphere extension and rifting all over the Pannonian area (Horváth, Tari 1999; Horváth et al. 2006). During this time the tectono-sedimentary evolution of the Mecsek area was characterised by the formation of transtensional half-grabens and pull-apart basins (Tari 1992; Benkovics 1997). The structural changes mainly from active syn-rift basin development to post-rift thermal subsidence combined with compressional events finally resulted in complete isolation of the Central Paratethys and the formation of Lake Pannon, which persisted during the Late Miocene to Pliocene (Magyar et al. 1999). Due to an early inversion event, a regional unconformity formed at the Sarmatian-Pannonian boundary (Horváth et al. 2006), which is also present in the marginal areas of the Mecsek region; in foreland basins, sedimentation was continuous across this boundary (Kleb 1973). The post-rift period covers mostly the Late Miocene and is characterised by thermal subsidence of the lithosphere and intense sediment accumulation in the basinwide Lake Pannon (e.g. Juhász et al. 2007). The Mecsek formed an island in the lake during most of the Late Miocene (Sebe et al. 2013; Sztanó et al. in press). After minor compressional events during post-rift subsidence (Csontos 1995), basin inversion started from the Late Miocene and dominated the Pliocene to recent time interval and caused reverse or oblique reverse faulting, uplift and erosion in the Mecsek (Bada et al. 2007; Wein 1967; Némedi Varga 1983; Tari 1992; Csontos et al. 2002; Konrád, Sebe 2010). Neogene sediments are widely distributed in and around the Mecsek Mts. (see geological map on inner front cover).

Knowledge on the stratigraphy of Neogene sediments in the Mecsek region was summarised by Hámor (1970) for the eastern and by Chikán (1991) and Barabás (2010) for the western part of the mountains; the following descriptions strongly rely on these works.

In the Mecsek Mountains and in the surrounding areas to the north, three Early to Middle Miocene sedimentary cycles mostly representing the syn-rift sedimentary fill of the Pannonian Basin have been identified by Hámor (1970) based on transgressional and regressional characters of the sedimentary successions (see stratigraphic chart on inner back cover). The Upper Miocene sediments, which were deposited in Lake Pannon, comprise another tectonostratigraphic unit and reflect the post-rift thermal subsidence, interrupted by several compressive events, which finally led to the inversion of the Pannonian Basin during Pliocene and Quaternary times.

The stratigraphic chart was compiled using the chronostratigraphic frame of Piller et al. (2007) and Hohenegger et al. (2014). The sedimentary formations were primarily placed in this chart based on biostratigraphic data like NN zones. However, at several locations biostratigraphically indicated ages and available K-Ar radiometric datings of interfingering volcanic rocks strongly disagree: the latter are usually older, and differences can exceed 2 Ma. This question needs to be clarified in the future.

The first Neogene sedimentary cycle in the Mecsek and in SW Hungary is built up of Eggenburgian to Karpatian terrestrial deposits of large alluvial fans, fluvial channel and floodplain deposits and paludal/lacustrine sediments (*Szászvár Formation*). The fluvial pebbles were widely studied (Józsa et al. 2009) and suggest a mountaneous source area mainly in the south. By revealing different lithological units (Carboniferous granite, Permian rhyolite and sandstones, Triassic to Jurassic sandstones and carbonates) now deeply buried as the basement of the Pannonian Basin, these pebbles are indicators of subaerial exposure of the basement at that time. The Szászvár Fm. contains interbeds of the *Gyulakeszi Rhyolite Tuff*, which were dated as Eggenburgian - Otnangian in the Mecsek, with K/Ar ages ranging between ~22-18 Ma (Árva-Sós, Máthé 1992; Barabás 2010); however, recent Ar/Ar and U-Pb datings point to a Karpatian age of the formation in Northern Hungary (Pálffy et al. 2007).

The first cycle is closed by the "Old Styrian" unconformity (Hámor 1970); other opinions report interfingering of sediments at this boundary (Barabás 2010). In the studied area, the Karpatian/Badenian boundary was conventionally placed at this unconformity, which was thought to be coeval with the *Tar Dacite Tuff*. The K/Ar age of the tuff is 15.3-17.4 Ma in the Mecsek area (Árva-Sós, Máthé 1992) and 16 ± 0.7 Ma in the Tengelic-2 borehole (Halmai et al. 1982).

The presence of thick dacite tuffs is interpreted to indicate a tectonic influence nearby (Tari 1992); multiple tuff horizons indicate repeated volcanic activity from Karpatian to Badenian times (for newest (U-Th)/He and U-Pb zircon chronological data of the formation in N Hungary see Lukács et al. this volume).

Approximately at the boundary between the first two sedimentary cycles or shortly after that, intermediate volcanism produced mostly volcanic, partly subvolcanic rocks (*Mecsek Andesite Fm.*) (Hámor 1970). Published K/Ar ages are 20.5 ± 0.8 Ma (Árva-Sós, Ravasz 1976) and 19.5-19 Ma (Széky-Fux et al. 1991); however, the andesite overlies and intrudes siliciclastics of the Szászvár Fm. and rhyolite tuffs.

During the Latest Karpatian or Early Badenian, *Congeria*-bearing sands (Stop1) and fish-scale-bearing claymarl (*Pécsvárad* and *Komló Members of Budafa Fm.*) represent a transition from brackish water to fully marine conditions. The large number of specimens with respect to low diversity in the *Congeria*-bearing sands may indicate stressed environmental conditions in brackish waters. The Komló Member contains massive or laminated claymarls with high organic content and was interpreted partly as a lagoonal deposit and partly as offshore sediment (Hámor 1970; Barabás 2010). The overlying clastics of the *Budafa Sandstone Member* of the same *Budafa Fm.* were deposited in nearshore (Stop 2), while the silty *Tekeres Schlier* in offshore marine environments. The Budafa Mb. consists of basal conglomerates and thick sandstones with normal marine biota. The Tekeres Schlier Fm., rich in micro- and macrofossils, used to be referred to as an upper neritic or shallow sublittoral deposit (Hámor 1970; Korecz-Laky 1982; Nagy et al. 1982). However, based on quantitative evaluation of planktonic and benthic foraminifers it was demonstrated that the schlier was deposited between sublittoral and bathyal depths (100-600 m) (Báldi et al. 2002). Water depth is also indicated by intercalations of turbidites and slump units. In the Northern Mecsek area the borehole Tekeres-1 revealed a deepening of the basin to at least 400 m during the NN5 zone. This estimation agrees with the presence of foraminifer species such as *Siphonia reticulata* and *Cibicides kullenbergi*, and mollusc species as *Amussium denudatum* (Bohn-Havas 1982). Still within nanno zone NN5 (Nagymarosy 1985) a significant shallowing took place, resulting in water depth less than 100 m with a transition to the *Szilágy Claymarl*. The same event is also reflected in the nearshore environment where deposition of the Leitha Limestone begun (*Pécsszabolcs Member*). Locally even subaerial erosion of former basin-fill deposits occurred (Hámor 1970; Tari 1992) marking the end of the second depositional cycle. The boundary is named as the "Young Styrian (or Leitha) unconformity" (Tari 1994).

The *Turritella-Corbula*-bearing Szilágy Claymarl represents the shallow open marine realm. This interfingers with the Lithothamnium-bearing lower and upper Leitha limestones (*Pécsszabolcs* and *Rákos Members of the Lajta/Leitha Limestone Fm.*) both formed in the nearshore to coastal zone. The *Pécsszabolcs Limestone* ("lower Leithakalk") is about 30-50 m thick and is actually a mixture of basal breccias and conglomerates, glauconitic sand(stone)s, bioclastic limestones and mollusc-, echinoidea- and bryozoa-bearing calcareous sands and silts (Stop 2, Stop 5). Its rich macrofauna contains *Pecten*, *Ostrea* and *Glycymeris* and points to the *Chlamys elegans/Pecten revolutus* subzone of the *Flabellipecten besseri* assemblage-zone (Bohn-Havas et al. 1987). Among the foraminifers benthic forms such as *Heterostegina*, *Amphistegina* and *Miliolina* are frequent (Korecz-Laky 1968). During the NN5 chron bathymetric changes created by eustatic sea-level changes were about an order of magnitude smaller than movements of the basin floor, therefore accommodation space was determined by structural events rather than eustasy, thus the "Young Styrian unconformity" between the second and third sedimentary cycles is also considered to be tectonically controlled (Tari 1992; Báldi et al. 2002). The Late Badenian (NN6 zone) and Sarmatian was characterized by a relatively low subsidence rate and presumably quiet tectonism, when eustatic sea-level fluctuation may have played a role in the development of accommodation space (Báldi et al. 2002). The *Hidas Brown Coal* above the erosionally truncated surface of the *Pécsszabolcs Limestone* ("lower Leithakalk") marks a transgressive event (Kókai pers. comm.) at the beginning of this cycle, which resulted in the formation of limnic to paralic coal measures up to a thickness of 50-100 m. The "upper Leitha Limestone" (*Rákos Limestone*) is up to 130 m thick. It was deposited in the shallow littoral zone, and points to the following highstand.

In the Sarmatian, beginning isolation of the Central Paratethys resulted in development of brackish waters. Rocks of this stage conformably overlie the Badenian deposits, with characteristic lithofacies and a macrofauna different from the previous euhaline faunas. Along margins they are represented by the 20-80 m thick *Tinnye Fm.*, a bioclastic, frequently ooid-bearing limestone formed in strongly agitated shoreface waters (Stop 3). This deposit interfingers with the greenish grey claymarls of the offshore *Kozárd Fm.* The Sarmatian-Pannonian unconformity (Horváth et al. 2006) closing this cycle is lacking in deeper foreland basins but is characteristic in marginal areas (Kleb 1973). It is manifested in the lack of early Pannonian calcareous marls along the margins and the locally strong deformation of the Sarmatian sediments (Stop 3). This event further complicated the basin topography, creating a considerable relief for the floor of the Late Miocene Lake Pannon, including both deep sub-basins and elevated basement highs in close proximity.

The Late Miocene (Pannonian) of the Mecsek area is particularly exciting, as it reflects deposition on or nearby an elevated basement block not far from one of the deepest troughs, the Drava Basin. Sedimentation in the deep basins follows a uniform pattern from the earliest Pannonian to Pliocene: the succession includes profundal marls (*Endrőd Fm.*), basin-center turbidites (*Szolnok Sandstone*), slope shales (*Algyő Fm.*), stacked deltaic successions (*Újfalú Fm.*) and finally alluvial deposits (*Zagyva Fm.*). These formations reflect the gradual filling of these basins due to high sediment supply from Alpine-Carpathian source areas (Magyar et al. 2013) and were also described from the Drava Basin (Saftić et al. 2003). Evolution of basement highs was different. The central part of the Mecsek emerged as an island for most of the Pannonian and only its margins were flooded. Here, as siliciclastic input was negligible (due to topography or climatic reasons), deposition of calcareous marls (formerly described as Csákvár, now *Endrőd Fm.*) prevailed (Stop 4; Sebe et al. 2015a). Flooding of the island was marked by shoreface or deltaic deposits of local origin (*Kálla Formation*; Stop 4), and happened in the majority of the area in the *Galeacysta etrusca* dinoflagellate (Sütő-Szentai 1995) and *Congeria rhomboidea* sublittoral and *Prosodacnomya* littoral mollusc zones (Magyar, Geary 2012), i.e. at about 8 Ma ago or thereafter (Sebe et al. 2013, Sztanó et al. in press). The prograding delta system reached the area shortly after the inundation, still within the same biochrons, and changed the depositional environments depending on the water depth of the given location. Where water depth reached a few hundred meters, slope shales and related turbidite accumulations may have followed, but these areas lack thick accumulations of both profundal marls and turbidites. This occurred mostly in the transition zone between the Drava trough and the Mecsek. Where water depth was shallow, deltaic successions (*Újfalú Formation*) followed without underlying slope deposits (Sztanó et al. in press).

During the Pliocene compressional tectonics resulted in differential subsidence of foreland basins and uplift of the Mecsek and its vicinity (Csontos et al. 2002; Konrád, Sebe 2010), while in the Drava trough a thick pile of alluvial deposits accumulated. Other Pliocene sediments are only known in the Villány Hills, 30 km south of the Mecsek Mts.; they are karstic cavity fills of mostly red clay with locally abundant vertebrate fossils. They span the time interval from 3.3 Ma to the late Pleistocene and include the type localities of Csarnotium (Csarnotien) and Villanyium (Villanyien) (Jánossy 1986; Koloszá 2004). During the Quaternary uplift continued in the Mecsek, alluvial deposition continued in the basins, while the Villány Hills represented a relatively stagnant transitional area in between (Sebe et al. 2015b). In the mountains loess deposition, erosion and gravity-driven transport became dominant.

1. LOVÁSZHETÉNY, KARPATIAN-BADENIAN *CONGERIA* SHELLBEDS



Fig. 1.1 Exposure of the *Congeria* beds south of Lovászhetény

The small, yet stratigraphically important exposure (Fig. 1.1) is a beautiful example of the “*Congeria* beds”, classified into the Pécsvárad Limestone Member of the Budafa Formation. The exposed 4 m of sediment are made up of fairly continuous beds of bioclasts with some sandy matrix and of few cm to dm thick sand and calcareous sand layers (Fig. 1.2). The coarse, sandy bioclastic layers are flat, thin-bedded, rarely with very low-angle cross-bedding, pointing to high-energy deposition in strongly agitated foreshore waters. Both moulds and shells are common; beside the dominant *Congeria* fossils, small gastropods also occur in the outcrop (Fig. 1.3).

The dominant fossils of the *Congeria* beds are *Congeria boeckhi* Wenz and *Bulimus vadaszi* Wenz (Hámor 1970). They are mixed with unidentified *Congeria* sp. and with freshwater faunal elements like *Theodoxus* (Nagymarosy, Hámor 2010); *Brotia* specimens are often worn and are probably redeposited (Hámor 1970).



Fig. 1.2 Close-up of a *Congeria* bed



Fig. 1.3 A) *Congeria* and gastropod moulds (image width 10 cm); B) Double-valved *Congeria* (length 4 cm)

The *Congeria* beds represent marginal conditions and usually unconformably overlie the older Miocene deposits or the Paleo-Mesozoic basement. In the surroundings of the Lovászhetény exposure, they represent the first Miocene sediments and overlie Carboniferous granite. In the basins where sedimentation was continuous, they are replaced by the “fish-scale bearing claymarl” (Komló Mb. of the same Budafa Formation) (Hámor 1970).

This deposit indicates the transition from the mostly terrestrial to lacustrine Karpatian to fully marine Badenian part of the succession. As the fossils point to marginal brackish waters, it is difficult to assess its age. Elsewhere the *Congeria* beds interfinger with the “fish-scale bearing claymarl”, which is regarded as earliest Badenian in age (NN4, rare forams; Nagymarosy, Hámor 2012), therefore the age of the *Congeria* beds can be late Karpatian or early Badenian.

2. FAZEKASBODA, BADENIAN ROCKY COAST AND FOSSILIFEROUS CALCAREOUS SAND

In this outcrop coarse-grained strata of the Budafa Formation are unconformably overlain by fossiliferous sands of the “lower Leitha limestone” (“Leithakalk”; Lajta Limestone Fm., Pécsszabolcs Member) (Fig. 2.1) (Hámor 1970). The section and its fauna are poorly known in the literature. Vadász (1935) mentioned Fazekasboda and indicated „Helvetian-Tortonian” beds at the sand pit. Köhler (1995) studied the Middle Miocene (Badenian) echinoid fauna of four localities in the Mecsek Mts. in his unpublished MSc thesis, including also the Fazekasboda locality.



Fig. 2.1 Overview of the Fazekasboda sand pit

Siliciclastic sediments of the Budafa Fm. in the area directly overlie the crystalline basement, Carboniferous granite, which is only a few tens of metres below the outcrop. In the sand pit, the lowermost bed consists of poorly sorted, chaotically arranged angular to subangular blocks in a very coarse sandy matrix. The largest clasts with diameters over 60 cm accumulated towards the top of the bed. Clasts at the top are subangular to well-rounded, with roundness increasing with decreasing clast size (Fig. 2.2). These are overlain by 2 m thick, fairly well-sorted, coarse-grained arcotic sand. The next bed is a lens of a coarse cobble to boulder breccia of granite again, laterally overlain with greenish grey clayey sand/sandy clay. The clasts were derived directly from the Carboniferous granites cropping out nearby.

The boulder breccias indicate transgression at a time when the granite was cropping out. The large blocks indicate steep topography with gravity mass movement events, this may point to some structural control which formed cliffs of the granite. The angular shape of these blocks, with rounding present only at the top of beds and only minor abrasion on large clasts, reveals deposition below or very near to wave base, where wave energy was able to move only pebble-cobble sized material, thus only the top of the coarse beds was abraded. No fossils have been found in the described beds.

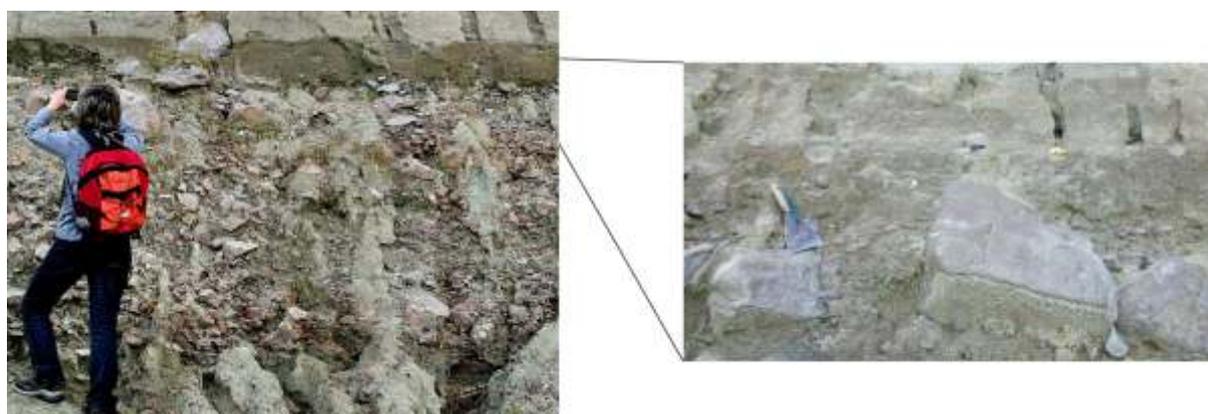


Fig. 2.2 Coarse granite breccia with wave-eroded top

After an erosional surface truncating both granite breccia and clayey sand, fossiliferous sands and sandy limestones of the Pécsszabolcs Member of the Lajta Limestone Fm. (Leithakalk) follow. The lower part of the formation is a sandy, pebbly limestone, where the bulk of the rock is constituted by cementing corallinacean algae. It contains scattered echinoids and molluscs including large ostreids, pectinids and gastropod moulds. This bed is overlain by grey, yellowish grey, coarse to very coarse grained, calcareous sand, which contains a considerable amount of bioclasts, both fragments and entire specimens of mostly molluscs and echinoids.

The red algal calcareous sandstone at the upper part of the section contains some mollusc fossils. An unidentified colonial coral was also observed in the field. A small fauna collected here consists mainly of ostreid and pectinid bivalves (Fig. 2.3). The majority of ostreids belong to thin-shelled *Ostrea digitalina*. Most of them are small-sized specimens (1-3 cm), but the largest ones attain a length of 9 cm. Thick-shelled *Crassostrea* specimens also occur. Pectinids are represented mainly by *Flabellipecten besseri*, from small juvenile specimens to very large fragments. One small fragmentary specimen probably belongs to *Flexopecten lillii*. Internal moulds of *Glycymeris deshayesi* and an indeterminable conid gastropod were also found here.

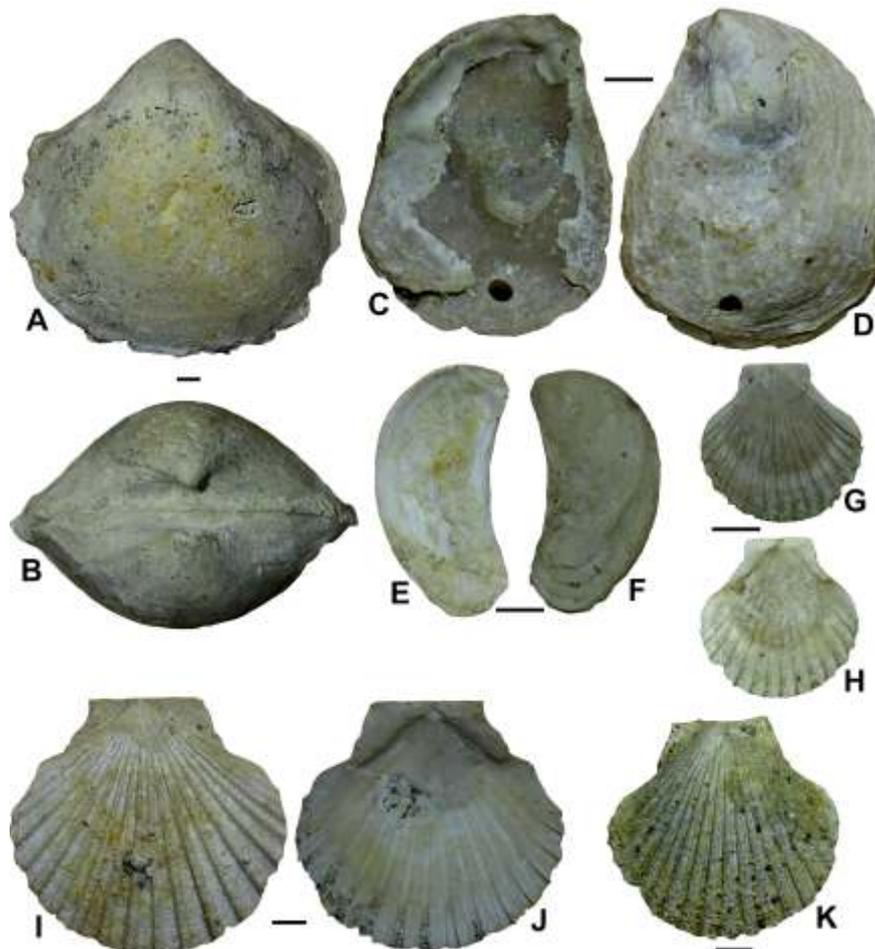


Fig. 2.3 Mollusc fossils from Fazekasboda. A)-B) *Glycymeris deshayesi* internal mould; C)-D) *Ostrea digitalina*, C) internal view, D) external view; E)-F) *Ostrea digitalina*, E) internal view, F) external view; G)-H) *Flabellipecten besseri*, left valve, G) external view, H) internal view; I)-J) *Flabellipecten besseri*, left valve, I) external view, J) internal view; K) *Flabellipecten besseri*, right valve, external view. Scale bars represent 5 mm. (Photos by Dávid Dulai.)

The overlying grey, yellowish grey sand contains a relatively rich Echinodermata fauna (Fig. 2.4). The echinoids were collected partly by Köhler (1995) but—along with the vertebrate remains—mainly by three private collectors (Tamás Bertalan, László Sövény, Zoltán Orbán). According to Köhler (1995), the echinoid fauna consists of several species of *Clypeaster* and *Parascutella* (*Clypeaster acuminatus*, *C. crassicostatus*, *C. sardiniensis*, *C. alticostatus*, *C. campanulatus partschi*, *Clypeaster* sp., *Parascutella vindobonensis*, *P. gibbercula*, *P. multiconcava*, *Parascutella* sp., *Echinolampas hemisphaericus*).

Echinoid specimens are generally well-preserved, sometimes with signs of regeneration. The fauna seems to be autochthonous: very few upside down specimens are present, *Parascutellas* can be found in smaller groups, apical plates are present (Köhler 1995). *Parascutella* is more common in the field, however, *Clypeaster* is easier to prepare and therefore it is more frequent in private collections. According to Köhler (1995) the taxonomical composition of the echinoid fauna refers to a very shallow environment (flat, nearshore, 1-2 or maximum 10 m deep). One of the *Clypeaster* specimens shows abnormal development with four ambulacral zones instead of the usual pentaradial symmetry (Fig. 2.4). It is a rare phenomenon, only one similar Miocene *Clypeaster* specimen was mentioned by Szörényi (1937) from the Badenian Leitha Limestone of Mátraszőlős (Cserhát Mts., N Hungary). The echinoid-rich sand was devoid of foraminifers or calcareous nannoplankton (Köhler 1995).



Fig.2.4 *Clypeaster* (length 15 cm) and *Parascutella* (diameter 12 cm) from the upper part of the outcrop.

The vertebrate material includes mostly fish fossils (Fig. 2.5). Among bony fishes, the typical molariform, conical and incisiform Sparidae teeth are common, but a chiseltooth wrasse (*Trigonodon jugleri*) pharyngeal tooth plate has also been found. Chondrichthyes include numerous shark species: requiem sharks (e.g. *Carcharhinus priscus*), mako sharks (*Cosmopolitodus hastalis*), sand tiger sharks (Odontaspidae spp.), tiger sharks (*Galeocerdo aduncus*) occurred here. These macropredatory sharks probably preyed on the local bony fishes. These taxa refer to warm, normal salinity water and tropical-subtropical climate (Compagno 1984; Bene 2003; Juhász 2006; Leriche 1936). The fish species are mostly nectonic, and all of them are typical for the Badenian in Europe (see Radwański 1965; Solt 1987; Hiden 1994/95; Holec et al. 1995; Holec 2001; Marsili et al. 2007; Schultz et al. 2010).

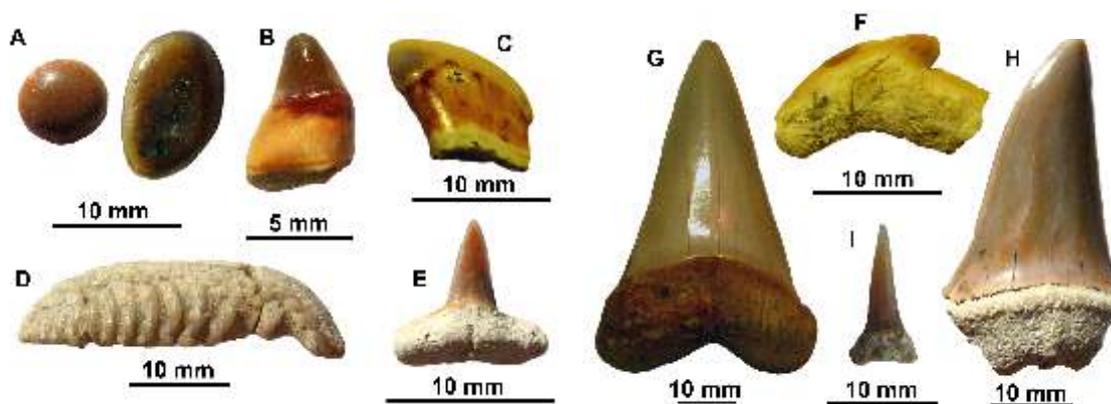


Fig. 2.5 Fish remains from Fazekasboda. **A)** Sparidae indet. molariform teeth (apical view); **B)** Sparidae indet. conical tooth; **C)** *Trigonodon jugleri* incisiform tooth (labial view); **D)** *Trigonodon jugleri* pharyngeal tooth plate; **E)** *Carcharhinus priscus* tooth (lingual view); **F)** *Galeocerdo aduncus* tooth (lingual view); **G)** **H)** *Cosmopolitodus hastalis* teeth (**G)** anterior tooth, **H)** lateral-anterolateral tooth; both in lingual view); **I)** Odontaspidae indet. tooth (lingual view)

From the locality Kordos (1992) mentioned Sirenia remains (Fig. 2.6) and provisionally ranked them into the *Metaxitherium* genus. Recently Domning and Pervesler (2012) prepared a more precise description and they ranked the Fazekasboda remains (partial juvenile skull, mandible and maxilla fragments with teeth, postcranial fragments) into *Metaxitherium medium* (DESMAREST, 1822) HOOJIER, 1952



Fig. 2.6 Sirenia remains

3. PÉCS, HAVI-HEGY, SHALLOW-WATER SARMATIAN LIMESTONE

The hill got its name [“havi” means connected to snow] after the chapel on the hilltop, built in gratitude to Our Lady of the Snows (Sanctae Mariae ad Nives) after the plague epidemic in 1690–91. The citizens of Pécs carried the building stones up the hill on their shoulders. The ridge displays characteristic lithofacies of the Sarmatian shallow-water limestones (Tinnye Formation) (Fig. 3.1).



Fig. 3.1 Panorama of Havi Hill with the visited outcrops and geological map showing the folded Sarmatian limestone

The Tinnye Formation formed along the margins of the Sarmatian sedimentary basins, and comprises a wide variety of rocks (greyish-white, yellowish-white, grey limestone, calcareous sand, calcarenite) depending on the environmental and energy conditions at the site of deposition. Its thickness in the Mecsek region ranges from a few tens of metres to ~150 m.

The Sarmatian succession of the Havi Hill and in its vicinity represents a marginal facies of the Tinnye Formation and a dominated by thick-bedded limestones. They are heavily deformed with tight folds of E-W axes and are in the hanging wall of the marginal fault of the Mecsek, with the Middle Triassic limestones thrust on them. They are overlain by much less deformed upper Pannonian gravelly sands (Konrád, Sebe 2010), thus the main deformation can be attributed to the Sarmatian-Pannonian inversion event of Horváth et al. (2006). However, fault breccias in a cave within the hill refer to multiple tectonic events (Sebe, Dezső 2008). Three main lithofacies can be distinguished in the area (Hámor 1970): a) yellowish or greyish-white oolitic calcarenite (composed of tiny mollusc shell fragments) and white, sandy oolitic limestone; b) yellowish-white, yellow thick-bedded mollusc-bearing porous limestone and c) yellow *Cerithium*-bearing limestone. The Sarmatian beds locally contain fragments of coralline algae reworked from the Badenian Leitha Limestone. Due to tectonic deformation, the stratigraphic order of the lithofacies on Havi-hegy is uncertain and difficult to study.

The dominant lithofacies at the site is the thick-bedded limestone with mollusc mould. It is most conveniently exposed at the northern part of the hill (see Fig. 3.1), where *Cardium* and *Calliostoma* are the most abundant macrofossils (Fig. 3.2 A, B). The microstructure of the limestone is characterized by a chaotic structure: besides the predominating grainstone texture, small patches of wackestone and packstone can also be observed (Fig. 3.2 C). Some fenestral (bird's eye) structures are also visible in thin sections, which may indicate temporary subaerial exposure. Fossils visible in thin section include poorly preserved foraminifer assemblage with benthic taxa (*Lobatula lobatula* (WALKER et JAKOB), *Varidentella* sp. (Fig. 3.2 D), Rotalidae and frequent Miliolidae), ostracoda shell fragments and *Calcisphaera*. The faunal association and the texture indicate very shallow (0–10 m), marginal, high-energy depositional environment. The salinity may have fluctuated between ca. 15–30 ‰. The predominating epifaunal genera (Miliolidae) point to the presence of rich sea-grass vegetation with hard substrates. High-energy environment is also indicated by intraclastic limestones, best visible in the middle of the hill, and mollusc coquinas (Fig. 3.3 A-C). According to the micropalaeontological investigations of Korecz–Laky (1968) in the Mecsek, the “Miliolidae facies” is present in earlier periods of the Early Sarmatian, both in marginal and basinal facies. Thus, despite the lack of index fossils, an Early Sarmatian age is suggested for the exposed beds.

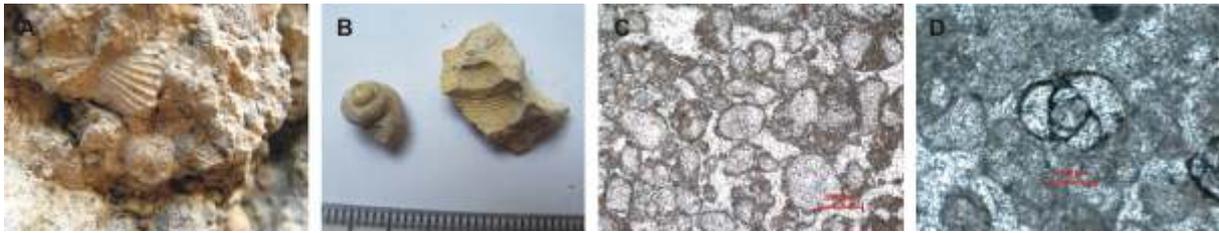


Fig. 3.2 Lithofacies of Sarmatian mollusc limestones. **A)** Typical appearance of limestone with mollusc moulds (here *Cardium*); **B)** inner mould of a Trochidae gastropod and outer mould of *Calliostoma* sp.; **C)** microstructure of the thick-bedded limestone; **D)** *Varidentella* sp.

At the southern end of the hill lies a block with large *Ostreas*, which are not typical in the Sarmatian of Hungary (Fig. 3.3 E). Its stratigraphic position is unclear due to soil cover, but micropaleontological investigation proved its Sarmatian age. The microstructure of the rock is chaotic, dominated by wackestone, with packstone and grainstone patches and bird's eye structures. In thin section foraminifers occur in low numbers in a poorly preserved assemblage with benthic taxa: *Ammonia beccarii* (LINNÉ), *Ammonia* sp. (Fig. 3.3 D), *Varidentella rotunda* (GERKE), *Cycloforina* sp., *Sinuloculina* sp., *Elphidium* sp., Miliolidae, Rotalidae. Further fossils are *Chara* oogonium fragment, gastropod shells and shell fragments (Fig. 3.3 D) and ostracods including *Xestoleberis* sp., *Fabaeformiscandona* sp. and unidentified shell fragments. Based on palaeontological and microfacies data, sedimentation took place in a coastal environment of very shallow water (0–10 m) characterized by low energy. The salinity content frequently fluctuated between 15–30‰, moreover, a freshwater inlet is indicated by the occurrence of *Chara* oogonia and *Fabaeformiscandona* sp. The predominance of the infaunal taxon *Ammonia beccarii* indicates loose substrate rich in nutrients. The rock sample yielded no index fossils. The probable age of the *Ostrea*-bearing block is Lower Sarmatian; the “*Ammonia beccarii* facies” appears above the “Miliolidae facies” both in basinal and marginal locations (Korecz-Laky 1968).



Fig. 3.3 Lithofacies of Sarmatian limestones. **A)** Thick-bedded limestones including intraclastic beds at the chapel; **B)** intraclastic limestone; **C)** mollusc coquina; **D)** gastropod shell (centre) and *Ammonia* sp. foraminifer (below, left) in the *Ostrea*-bearing block; **E)** large *Ostreas*.

4. PÉCS, DANITZPUSZTA, PANNONIAN SUBLITTORAL AND LITTORAL DEPOSITS WITH REWORKED MIDDLE MIOCENE VERTEBRATES

The sand pit at the eastern boundary of the city of Pécs exposes deposits of the Late Miocene (Pannonian) Lake Pannon. It represents the best outcrop of the calcareous marls and the overlying littoral sands together (Fig. 4.1), the two most typical lacustrine sediment types in the region. The succession is heavily tectonised due to intra- and post-Pannonian movements, thus the boundary between the two rock types is vertical (see cover photo), and younging is dominantly towards the south and not only upwards.



Fig. 4.1 Panorama of the Danitzpuszta sand pit



Fig. 4.2 Log of the upper part of the calcareous marl succession

The older deposits, now exposed in the northern wall of the sand pit, are primarily composed of massive, greyish white calcareous marls (analogous with “white marls” in Croatia and Serbia), with thin intercalations of clay, claymarl, sand and even fine gravel (Fig. 4.2). They become silty in the upper few metres, and show a relatively sharp but conformable boundary with the overlying sands. The calcareous marls contain abundant molluscs and also makroflora and scattered fish remains in the upper parts. Though traditionally interpreted as “lagoonal deposits” (Kleb 1973) and classified into the Csákvár Fm., they contain a sublittoral mollusc fauna and rather belong to the open-water Endrőd Fm. (Tótkomlós Calcareous marl Mb.) (Sebe et al. 2015a).

The overlying sands are worked in the sand pit. They are limonitic, yellow, coarse-grained, gravelly arkoses deposited in a littoral environment. The main provenance of sands is the area of the Carboniferous granite and Lower Miocene terrestrial clastic (Szászvár Fm.), i.e. they are of local origin and are thus classified into the Kálla Formation. Besides lacustrine molluscs, the sands contain abundant vertebrate fossils, the majority of them redeposited from older Miocene sediments (Kazár et al. 2007).

The whole succession underwent at least two phases of tectonic deformation (Konrád, Sebe 2010). The lower part of the sand contains normal faults and negative flower structures related to the activity of the southern boundary fault zone (Mecsekalja Dislocation Zone) of the Mecsek Mts. under a transpressional stress regime. These structures, together with the lower part of the succession including not only sand but also the white calcareous marl, later became heavily tilted to vertical and even overturned positions; they form part of a large-scale south-vergent fold according to Benkovics (1997). This may mark the onset of compressional tectonics, probably related to the earliest events of neotectonic inversion of the Pannonian Basin (Konrád, Sebe 2010). This event, also producing angular unconformity within the sands documented in earlier publications (Kleb 1973) but not visible any more, happened during the deposition of the limonitic sands. Continuing tectonic activity is shown by the gradually decreasing dip of the overlying sand beds (Fig. 4.3) and the reverse faults crosscutting even the uppermost exposed lacustrine sediments.

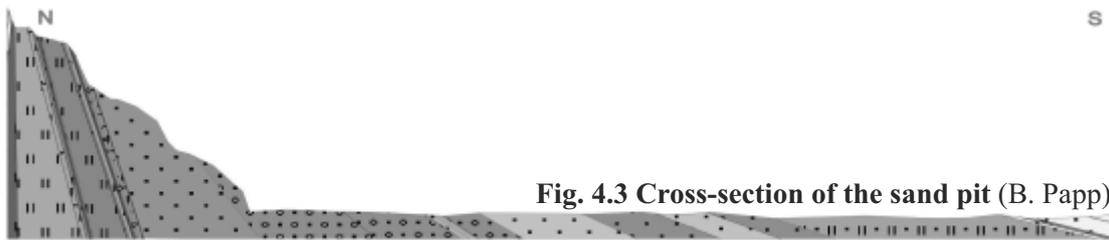


Fig. 4.3 Cross-section of the sand pit (B. Papp)

Calcareous nannoplankton from Danitzpuszta was investigated by Bóna, Gál (1985). They described a new genus, *Bekelithella*, and two new species, *Bekelithella echinata* and *Noelaerhabdus jerkovici* from the outcrop. Attempts to recover dinoflagellates from the calcareous marl have failed so far.

In the uppermost part of the white marls numerous plant remains – mostly leaves and wood fragments, but also fruits – have been collected recently (see Sebe et al., this volume). They indicate a thermophilous flora, with extensive swamp forests dominated by *Myrica lignitum* but also with an elevated background with rather mesophilous species like *Quercus kubinyii* and *Daphnogene pannonica*.

The calcareous marl contains abundant molluscan fossils (Fig. 4.4) (Rofrics 2015). The shell material is often dissolved, and in this case the molluscs are preserved as molds and prints. They are partly scattered in the sediment, partly accumulated on the bed surfaces. Bivalve valves are usually disarticulated. The identified forms include, among others, *Lymnocardium schedelianum*, *L. majeri*, *Paradacna abichi*, *P. cf. syrmienne*, „*Pontalmyra*” *otiofhora*, *Caladacna steindachneri*, *Congeria czjzeki*, *C. banatica*, *C. partschi*, *Gyraulus tenuistriatus*, and various species of *Orygoceras* and *Socenia*. This fauna unambiguously indicates a sublittoral depositional environment with low or occasionally moderate energy. Based on the presence of *Congeria czjzeki* and *Lymnocardium schedelianum*, these beds belong to the *Lymnocardium schedelianum* zone, having an age of 11 to 10 Ma.

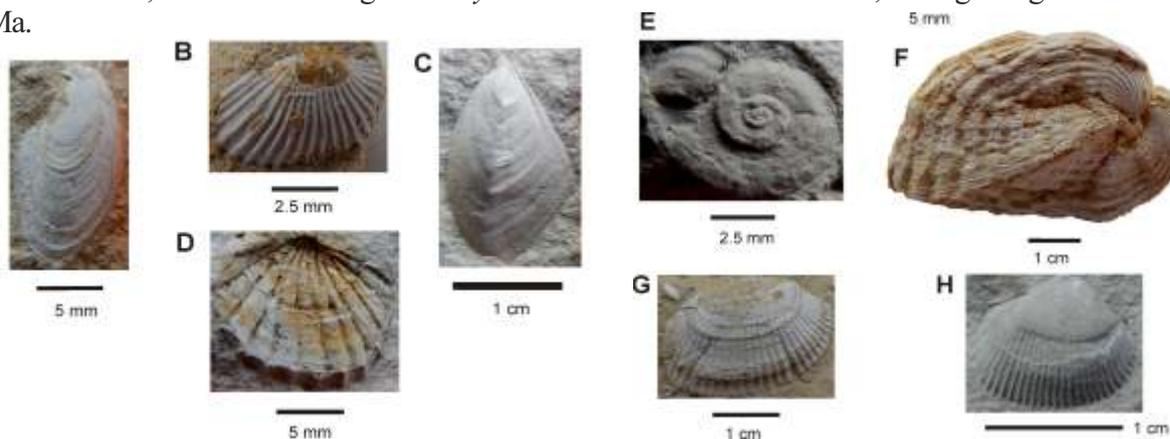


Fig. 4.4 Molluscs from the calcareous marl. **A)** *Congeria czjzeki*; **B)** *Paradacna cf. syrmienne*; **C)** *Congeria banatica*; **D)** *Paradacna abichi*; **E)** *Gyraulus tenuistriatus*; **F)** *Lymnocardium schedelianum*; **G)** *L. majeri*; **H)** *L. otiofhorum*

The sand beds overlying the white calcareous marls yielded only a few, poorly preserved molds of bivalve shells. This mold type is very common in the young Pannonian sands in the southern foreland of the Mecsek, including the proximal Hird outcrop (Mező et al. 1999); the Danitzpuszta fossils were therefore almost automatically identified with the large *Lymnocardium* and *Congeria* species found in those other outcrops. These latter species, such as *Lymnocardium schmidtii*, *Congeria rhomboidea* etc. indicate an age younger than 8 Ma, and this age was referred to the sandy series of Danitzpuszta (Kazár et al. 2007). The most recent findings, however, include some relatively well-preserved molds of *Congeria*, including *C. cf. ungulacaprae* and *C. cf. pancici* (Fig. 4.5), and this association suggests a significantly older age for the sand than thought before (9.5-10.0 Ma). Further investigation is required to establish the reliable biostratigraphic position of the sandy sequence.



Fig. 4.5 *Congeria cf. ungulacaprae* and *C. cf. pancici* from the limonitic sands

The Danitzpuszta sand pit is a most famous vertebrate locality in the region, the limonitic sand is rich in fish, reptile and mammal remains. The majority of them had been reworked from older Miocene sediments. Most fossils are in the property of private collectors; however, large amounts are stored in museal collections as well, like at the Geological and Geophysical Institute of Hungary and the Natural History Collection of Komló.

The most common vertebrate remains are fish fossils (Fig. 4.6). Among the bony fishes the remains of Sparidae are very abundant, several genera of the family were found at the locality, such as *Archosargus*, *Chrysophrys*, *Dentex*, *Diplodus*, *Pagellus*, *Pagrus*, *Sparnodus* and *Sparus* (Bene 2003). The roundish, shiny, button-like, molariform *Sparus umbonatus* teeth were collected in large numbers. Bony fish vertebrae, fin rays and other bones are also common; partially articulated skeletons have also been found, which exclude redeposition, thus belong to animals coeval with the deposition of the limonitic sands.

Ray remains (tooth plates and stings) belong to eagle rays (Myliobatoidea), but these genera are problematic to distinguish from each other (Zachár 2004). The locality is very rich in shark remains (teeth and vertebrae), the numerous identifiable taxa include *Notorynchus primigenius* (cow sharks), Odontaspidae spp. (sand tiger sharks), *Cosmopolitodus hastalis* (mako sharks), *Otodus (Megaselachus) megalodon* (megatoothed sharks), *Carcharhinus priscus* (requiem sharks), *Galeocerdo* spp. (tiger sharks), *Hemipristis serra* (snaggletooth sharks) and *Squatina* sp. (angel sharks).

The massive bony fish and ray populations could have been the main food sources for several macropredatory sharks, but probably the cetaceans and seals, represented by varied and numerous remains, were the main preys for megatoothed sharks. The diverse and mostly nectonic fish fauna is typical for the Badenian of Europe (see Radwański 1965; Solt 1987; Hiden 1994/95; Holec et al. 1995; Holec 2001; Marsili et al. 2007; Gregorová 2009; Schultz et al. 2010), and indicates subtropical climate and warm-temperate water (Compagno 1984; Bene 2003; Juhász 2006; Kocsis et al. 2009; Leriche 1936).

The reptilian remains include dominantly carapace fragments, sometimes teeth and osteoderms. They belong to turtles and supposedly also to unidentified crocodiles. Reported turtle genera are *Trionyx* and *Testudo* (Kazár et al. 2007; Konrád et al. 2010). These reptiles are mostly freshwater or terrestrial forms, and their presence refers to the proximity of a dryland with freshwater environments. Due to the very approximate identification of the fossils, no age can be assigned to them, they might have been redeposited from the Badenian dryland to the coeval sea (like e.g. in the case of the Sandberg locality; Hyžný et al. 2012), or may have lived around (or even in) Lake Pannon as well.

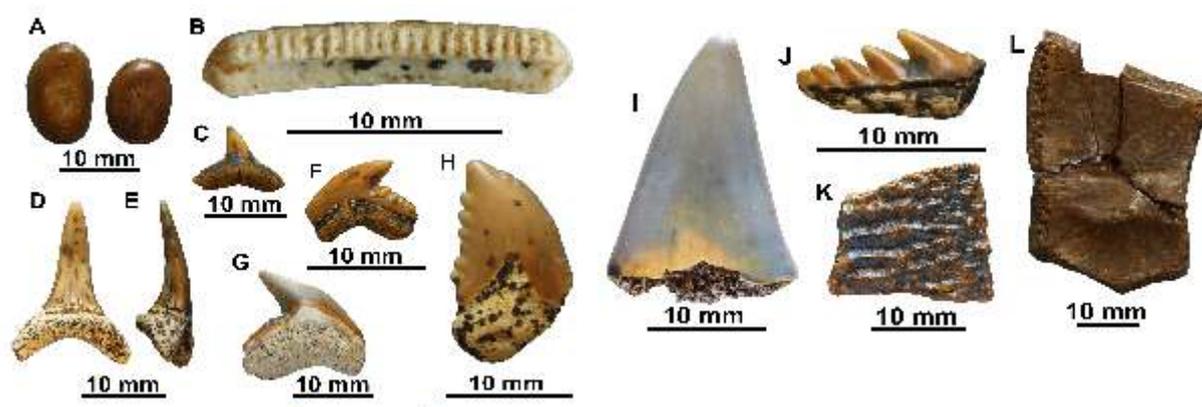


Fig. 4.6 Fish and reptile remains from Danitzpuszta. **A)** *Sparus umbonatus* molariform teeth (apical view); **B)** Myliobatoidea tooth plate (basal view); **C)** *Carcharhinus priscus* tooth (lingual view); **D)** Odontaspidae indet. tooth in lingual view; **E)** in mesial view; **F)** *Galeocerdo aduncus* tooth (lingual view); **G)** *Galeocerdo* cf. *latidens* tooth (lingual view); **H)** *Hemipristis serra* tooth (lingual view); **I)** *Cosmopolitodus hastalis* tooth (lingual view); **J)** *Notorynchus primigenius* tooth (lingual view); **K)-L)** *Trionyx* sp. carapace fragments

The locality shows extraordinary richness in marine mammal fossils. They include predominantly cetaceans (whales and dolphins) and sirenians, in smaller quantities pinnipeds (seals) (Fig. 4.7). In most cases these specimens are more or less worn indicating reworking; this is in accord with the original ages assigned to the identified taxa, which is Badenian and Sarmatian. The preservation of some seal remains is very good, they are quite unworn, so we cannot rule out the possibility that some populations also survived in Lake Pannon. However, some specimens among certainly Badenian fossils (e.g. shark teeth) also occur in perfect condition, thus preservation bears only faint reference to age.

Among whale and dolphin fossils, vertebrae and various fin bones are the most common, but some periotic bones occur as well. Beside the thousands of remains of Cetacea indet., Odontoceti indet., Mysticeti indet. and Delphinoidea indet., up to now the following species are known from the locality (after Kordos 1992; Kazár 2003, 2005, 2006, and the list of items stored at the collection of the Geological and Geophysical Institute of Hungary): *Acrodelphis letochae* (BRANDT), *Pachyacanthus suessi* BRANDT, cf. *Heterodelphis* n. sp., *Kentriodon fuchsii* (BRANDT) (earlier *Atocetus fuchsii*), *Sophianaecetus commenticius* (KAZÁR), ? *Nannolithax gracilis* KELLOGG, cf. *Mesocetus brachyspondylus* (BRANDT).

Sirenians are most commonly represented by rib fragments, which are usually rather worn, indicating redeposition. Occasionally isolated teeth can also be found. The hundreds of Sirenia indet. specimens very probably belong to the genus *Metaxitherium*.

Seal fossils are usually limb bones or their fragments. Beside the several Phocidae specimens only one species, *Praepusa magyaricus* KORETSKY has been described from the locality. The generic name *Praepusa* indicates probable relationship with the extant caspian seal (*Pusa caspica*).



Fig. 4.7 Mammal remains from Danitzpuszta. 1) Sirenia indet. rib fragment; 2) Large sized Bovidae indet. calcaneus fragment; 3) Small sized artiodactyl (? *Procapreolus* sp.) metapodial fragments; 4) Small sized artiodactyl (? *Dorcatherium* sp.) astragalus; 5) Medium sized artiodactyl (? Cervidaeindet.) premolar; 6) hipparion incisor; 7) Delphinoidea indet. vertebrae; 8) medium sized Suidae indet. metapodial fragment; 9) Seal (*Praepusa* sp.) femur fragment

Terrestrial mammalian remains are also abundant at Danitzpuszta and include hipparions, proboscideans, rhinocerotids, tapirs, suids and ruminants (bovids, tragulids and cervids) (Fig. 4.7). They indicate a mosaic of paleoenvironments with mainly forested areas but also with open grasslands. Unfortunately the record has been poorly studied so far. Up to now the following species have been described from the locality (see Kazár et al. 2001):

Proboscidea: cf. *Prodeinotherium bavaricum* von MEYER, *Deinotherium giganteum* KAUP, *Tetralophodon* cf. *longirostris* KAUP

Perissodactyla: *Tapirus* sp., *Aceratherium* sp., *Hippotherium primigenium* von MEYER

Artiodactyla: *Korynochoerus* sp., *Dorcatherium* sp., ? *Procapreolus* sp. (= *Lucentia* sp.), Bovidae indet. (large sized form)

Carnivora (Amphicyonidae): *Hubacyon pannonicus* Kretzoi, 1985

Most of the listed taxa represent a typical Early Pannonian (Vallesian) assemblage, a so-called Hipparion fauna. However, the presence of the small sized deinotherere (cf. *Prodeinotherium bavaricum*) refers to redeposition of fossils from older (Badenian and/or Sarmatian) sediments not only in the case of marine species, but also in the case of terrestrial taxa.

5. HETVEHELY, BADENIAN ROCKY SHORE AND FOSSILIFEROUS SHOREFACE SAND

At the end of the 1970s, a new railway cut was excavated NE of the village Hetvehely, which exposed a transgressive succession with large numbers of fossils. Though it is composed dominantly of clastics, because of its numerous, typical Badenian fossils it is classified into the “Leithakalk” (Lajta Limestone Formation, Pécsszabolcs Mb.). Due to recurring landslides the slope of the railway cut had to be terraced and vegetated, thus today only fragments of the original exposure are visible. Unfortunately the sections that contained the vertebrate fossils are covered and not accessible any more.

The exposure was thoroughly documented by Chikán, Konrád (1982) (Fig. 5.1). The succession begins with the wave-eroded basement built up of Middle Triassic limestone (Viganvár Fm.), showing ample signs of bioerosion, especially cavities produced by *Lithodomus* and by sponges (Fig. 5.2; for details see Dávid, Fodor this volume). It is followed by wave-worn, monomictic conglomerates, where pebbles are often bored by bivalves or bear *Balanus* shells and other attaching organisms. The overlying sediments are composed of gravelly sands and silts, are cemented by calcite in certain beds and contain abundant fossils, especially molluscs and echinoderms.



Fig. 5.2 Bioeroded Middle Triassic limestone at the base of the Badenian littoral succession

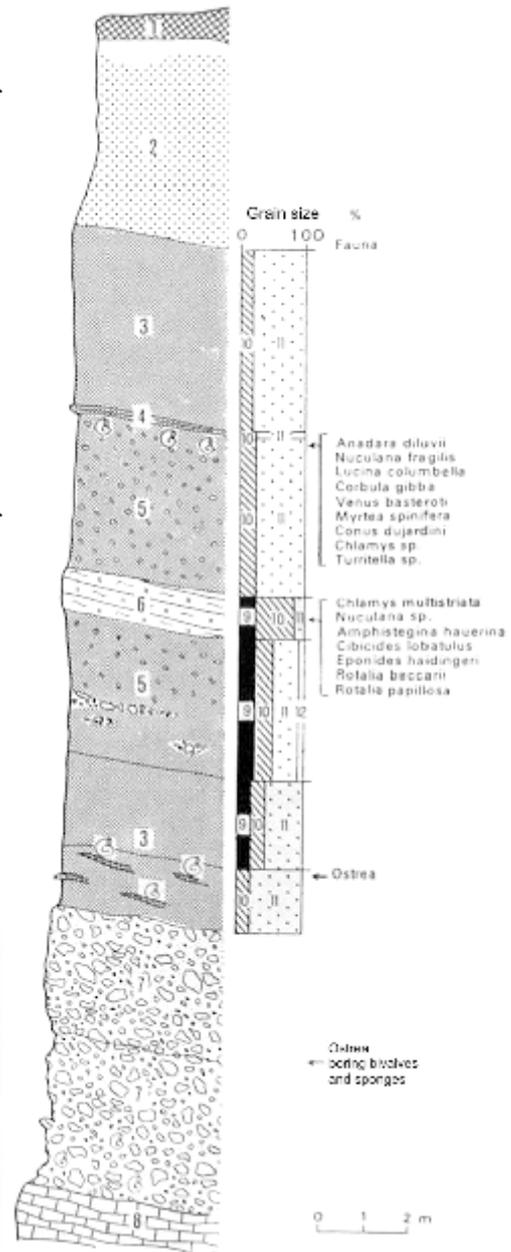


Fig. 5.1 Original section of the railway cut (Chikán, Konrád 1982).

1) debris; 2) clayey silt; 3) sand; 4) sandstone; 5) gravelly sand; 6) marly silt; 7) conglomerate; 8) Middle Triassic limestone; 9) clay; 10) silt; 11) sand; 12) gravel

The following description of the Hetvehely biota is primarily based on the article of Chikán, Konrád (1982), the MSc thesis of Hajas (1997) and the private collection of Mrs. Józsefné Vass. The first article mentioned only invertebrates; however, large amounts of vertebrate fossils were collected mostly by the local teacher, Mrs. Vass.

Middle Miocene flora is represented by coralline algae nodules („*Lithothamnium*”, however, it has never been studied in detail in the Hungarian Miocene). Washed samples have not been studied from Hetvehely, however, some larger foraminifers can be found in the field (*Heterostegina*). Reported foraminifers are *Amphistegina hauerina*, *Cibicides lobatulus*, *C. dutemplei*, *Eponides haidingerii*, *E. praecinctus*, *Rotalia beccarii*, *R. papillosa*, *Globigerinoides triloba*, *Nonion soldanii*, *Globorotalia scitula*, *Asterigerina* sp., *Heterostegina* sp. (Koreczné Laky in Chikán, Konrád 1982).

Mollusc taxa include *Chlamys* cf. *multistriata*, *Nuculana fragilis*, *Anadara diluvii*, *Lucina columbella*, *Venus basteroti*, *Myrtea spinifera*, *Conus dujardini*, *Corbula gibba*, and *Pitar*, *Venus*, *Turritella* and *Hinia* sp. (Bohn-Havas in Chikán, Konrád 1982). Based on our own data and private collections, further molluscs occur as well: several calcitic-shelled bivalves (pectinids, ostreids, anomiiids, *Spondylus*) as well as external and internal moulds of aragonitic-shelled bivalves and gastropods (Fig. 5.2). Pectinids are represented by *Pecten aduncus*. Ostreids include large and thick-shelled *Crassostrea* specimens, generally full of traces of different boring animals, and also thin-shelled forms. Traces of drilling predatory gastropods (Naticidae, Muricidae) are also common on bivalve shells. In some cases the internal moulds of bivalves are also easy to identify (e.g. *Panopea menardi*, *Cardium hians*). Bivalve shells are generally disarticulated, except for the burrowing forms, such as *Panopea*. Most common gastropods are different species of cone shells (Conidae). Some of the internal moulds may indicate *Conolithus dujardini* or related species. *Tudicla* is also present in smaller numbers.

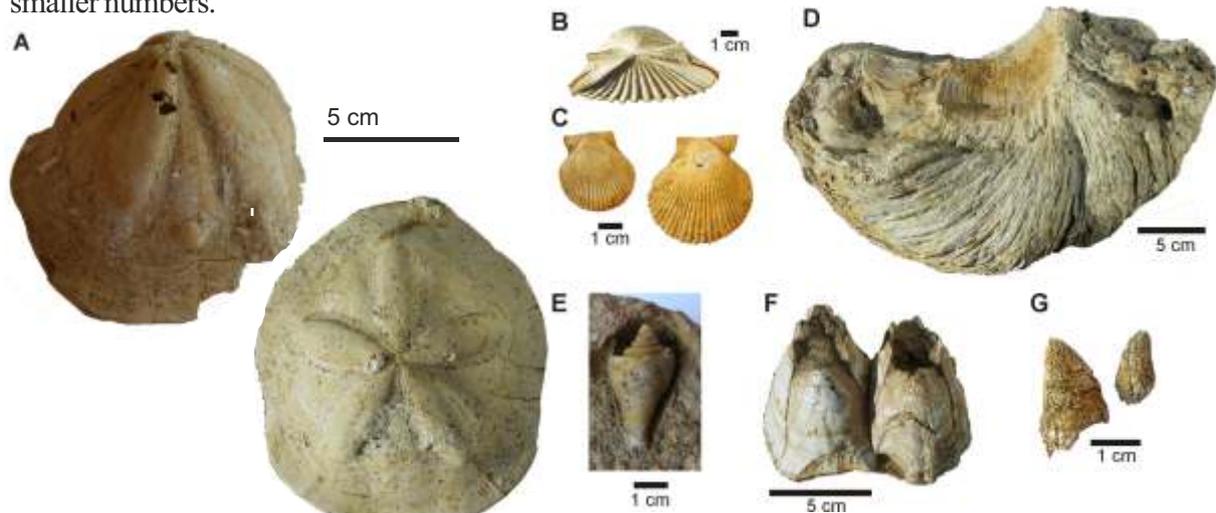


Fig. 5.3 Invertebrates from Hetvehely. **A)** *Clypeaster* spp.; **B)** *Pecten aduncus*; **C)** *Chlamys* sp.; **D)** *Crassostrea* sp.; **E)** *Conolithus dujardini*; **F)** *Balanus*; **G)** *Petrochirus priscus* fingers

Decapod specimens are very fragmentary and poorly preserved. Taxonomic identification of decapod fingers is really difficult. Two fingers of hermit crabs most probably belong to the genus *Petrochirus* (in the Paratethys area at that time only one species is known, *Petrochirus priscus*). A third specimen belongs to some crab, e.g. a member of infraorder Brachyura (det. Matus Hyzny, pers. comm.). Cirripeds are represented by several balanids, from mm size fragments to several cm large complete specimens. *Balanus* can be found not only as separated plates in the sediment, but also as whole specimens on pebbles, bivalves or echinoids. In several cases their attachment places can be seen on hard surfaces. Bryozoans may be common in washed samples, but some larger fragments can be collected even in the field. Echinoids are represented by different species of *Clypeaster*, as well as by small isolated plates from spatangoid echinoids (det. Andreas Kroh, pers. comm.). The surface of large echinoids may be covered by other attached organisms (e.g. oysters, anomiiids, balanids, worm tubes). Vertebrate remains from the locality are placed in museal and personal collections. Among them cartilaginous and bony fishes are by far the most common (Fig. 5.3). Several perciform (order Perciformes) taxa can be identified among the bony fish teeth. The roundish (molariform), the conical and the labiolingually flattened, anguil-like (incisiform) fish teeth belong to several different taxa, such as Sparidae genera (e.g. *Pagrus* and *Diplodus*). Pufferfish (Tetraodontidae) and barracuda (*Sphyraena* sp.) tooth remains have also been found. These bony fish forms live mostly in open waters, but sometimes both taxa occur in coastal environments. Among the ray fossils (stings and tooth plates) the most common, identifiable forms are eagle rays (Myliobatoidea): *Myliobatis* sp. and *Aetobatus arcuatus* (Zachár 2004). The most common shark families are Odontaspidae ('sand tiger sharks', e.g. *Carcharias cuspidata*) and Carcharhinidae ('requiem sharks', mostly *Carcharhinus priscus* and *Galeocerdo aduncus* [tiger sharks]), but teeth of hammerhead sharks (*Sphyrna zygaena*) and snaggletooth sharks (*Hemipristis serra*) have been found here as well, similarly to those of the biggest known macropredatory shark *Otodus* (*Megaselachus*) *megalodon* (common synonym: *Carcharocles megalodon*).

Rays, together with the bony fishes could have been the main food source for the numerous piscivorous shark forms, similarly to the case of extant tiger sharks, which often prey on barracudas. The occurrence of *Otodus (Megaselachus) megalodon* refers to the presence of sea mammals, potential prey for these gigantic sharks, and indeed *Sirenia* remains were found at the site (Hajas 1997). Among the local shark species the nectonic (freely swimming) lifestyle dominates and the tropical-subtropical distribution is typical, therefore, with the bony fish fauna, they refer to a subtropical climate with warm-temperate water (Compagno 1984, Bene 2003, Juhász 2006, Leriche 1936). All of the local fish forms are typical of the Badenian sediments of Europe, including several localities in Austria (Hiden 1994/95), Czech Republic (Schultz et al. 2010), Hungary (Solt 1987), Italy (Marsili et al. 2007), Poland (Radwański 1965), Slovakia (Gregorová 2009; Holec et al. 1995) and Slovenia (Holec 2001).

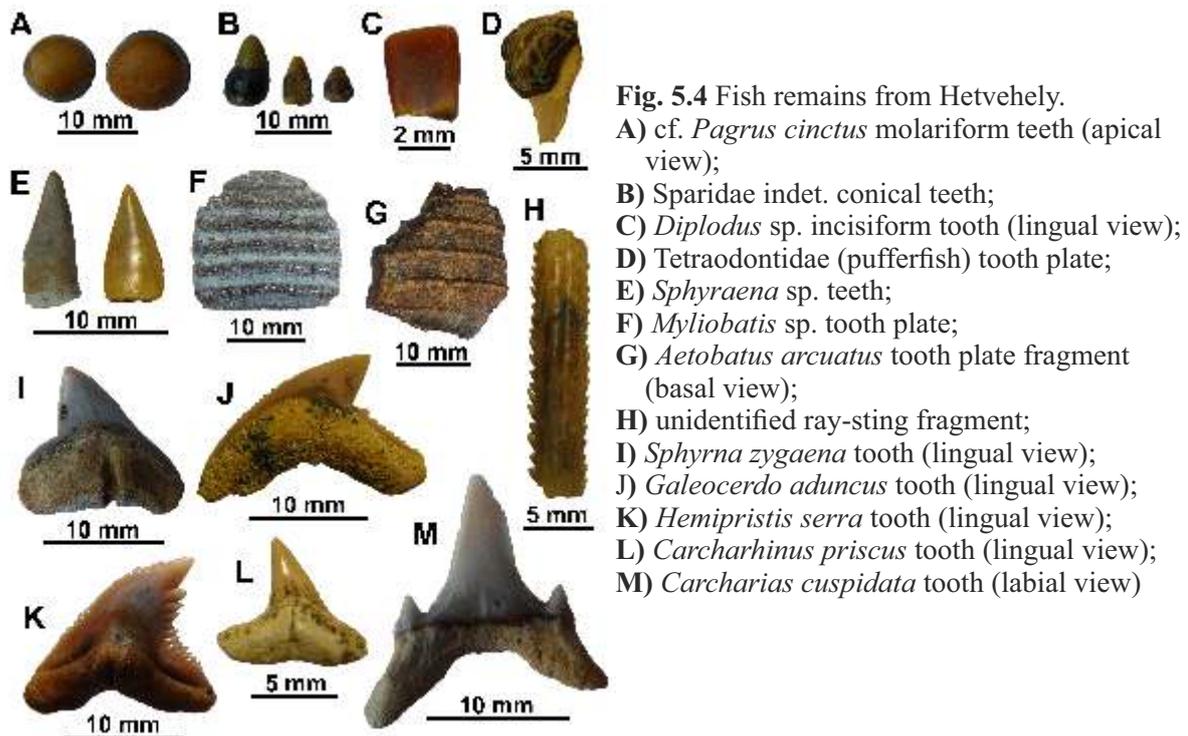


Fig. 5.4 Fish remains from Hetvehely.
A) cf. *Pagrus cinctus* molariform teeth (apical view);
B) Sparidae indet. conical teeth;
C) *Diplodus* sp. incisiform tooth (lingual view);
D) Tetraodontidae (pufferfish) tooth plate;
E) *Sphyraena* sp. teeth;
F) *Myliobatis* sp. tooth plate;
G) *Aetobatus arcuatus* tooth plate fragment (basal view);
H) unidentified ray-sting fragment;
I) *Sphyrna zygaena* tooth (lingual view);
J) *Galeocerdo aduncus* tooth (lingual view);
K) *Hemipristis serra* tooth (lingual view);
L) *Carcharhinus priscus* tooth (lingual view);
M) *Carcharias cuspidata* tooth (labial view)

From the locality a few terrestrial mammal taxa have been reported. Besides some - as yet unidentified - teeth (Fig. 5.5), a deinothere represented by a complete tooth and molar and tusk fragments were found by Józsefné Vass and depicted in the work of Hajas (1997) (Fig. 5.6). The complete tooth is a right upper first premolar (P3 dext.) of a *Prodeinotherium bavaricum*, the maximal length (55 mm) and max. width (ca. 50 mm) of the occlusal surface of the tooth suggest late Badenian age. From aquatic mammals, a *Sirenia* rib was found by Tibor Hajas (1997).



Fig. 5.5 Mammal teeth from the Hetvehely outcrop



Fig. 5.6 *Prodeinotherium bavaricum* upper right P3 tooth. Length (height of the crown plus length of the roots) 15 cm

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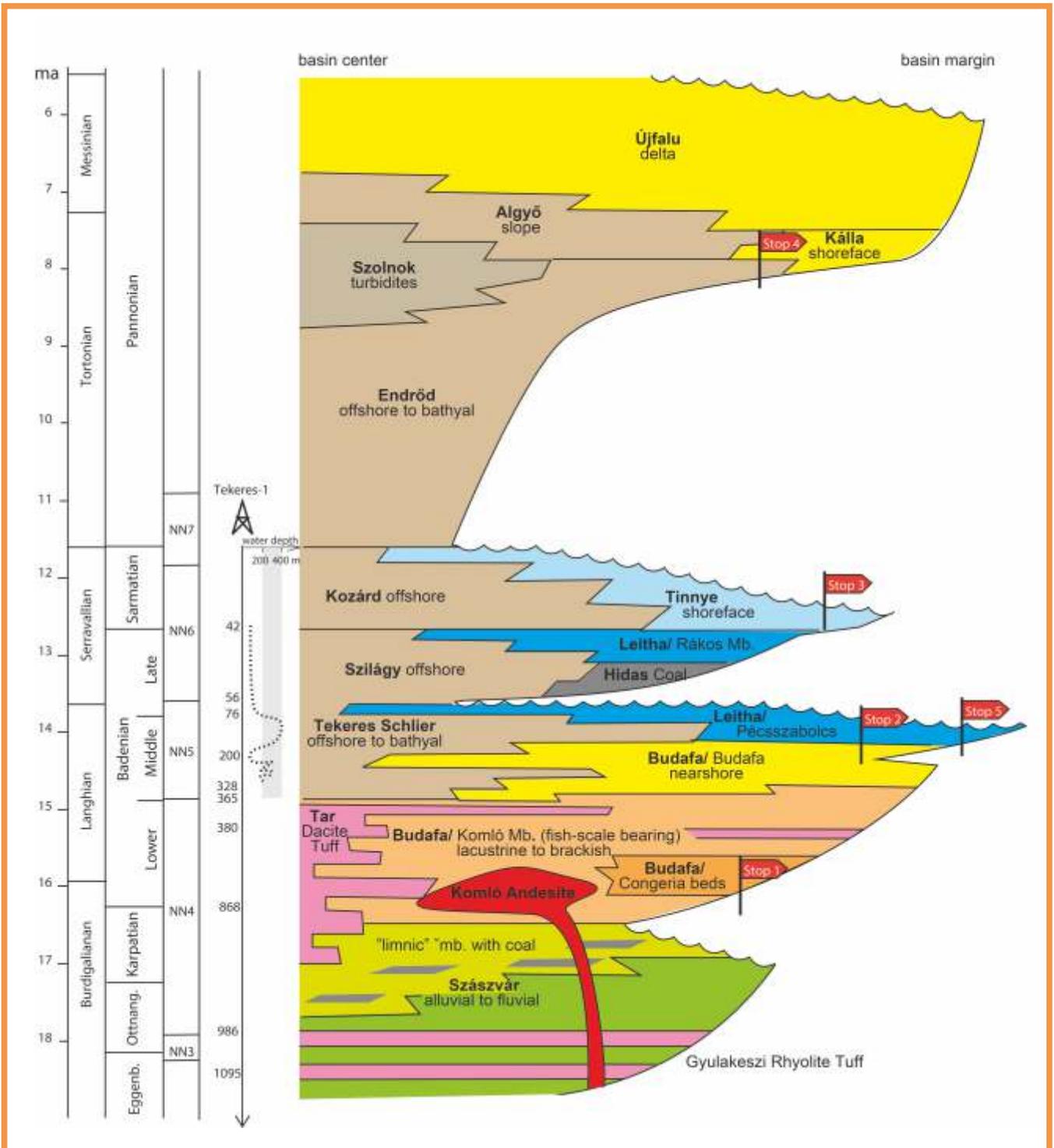
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Lithostratigraphy of Miocene deposits in the Mecsek region. The figure was compiled using data by Hámor (1970), Chikán (1991), Báldi et al. (2002) and Barabás (2010). Chronostratigraphic frame after Piller et al. (2007) and Hohenegger et al. (2014).

Fig. 0.0 Field trip route

1. Lovászhetyő, Karpatian-Badenian *Congeria* shellbeds
2. Fazekasboda, Badenian rocky coast and fossiliferous calcareous sand
3. Pécs, Havi-hegy, Sarmatian shallow-water limestone
4. Pécs, Danitzpuszta, Pannonian offshore and nearshore deposits with reworked Middle Miocene vertebrates
5. Hetvehely, Badenian rocky shore and fossiliferous shoreface sand

