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ABSTRACTS BOOK

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ABSTRACTS BOOK

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László Csontos

INVITED LECTURER

MOL PLC, Október huszonharmadika u. 18, 1117 Budapest, Hungary

lcsontos@mol.hu

For a type back-arc rift basin, the Pannonian Basin has a lot of inversion (or thrusting) episodes (HORVÁTH, 1995; FODOR et al., 2005). These can be separated into Paleogene-Early Miocene events, when the lithospheric substratum of the basin was assembled and into Late Miocene-Recent inversion events that followed rifting (CSONTOS & NAGYMAROSY, 1998).

The early inversion has multiple indications from Late Eocene through Oligocene and Early Miocene. In some regions folds and thrusts were formed, like in the Hungarian Paleogene basin (FODOR et al., 1999; CSONTOS & NAGYMAROSY, 1998), or the Southern foothills of Mecsek Mountains (CSONTOS et al., 2002). This episode is also present in Zagorje area of Croatia and in the Mid-Hungarian shear zone (TOMLJENOVIĆ & CSONTOS, 2001; CSONTOS et al., 2005).

The late inversion is more intense in the south, closer to the Dinarides (MÁRTON et al., 2002) although a general inversion affected the whole area in the Sarmatian (HORVÁTH, 1995; FODOR et al., 2005). Such inverted basins can be found as far east as the easternmost part of Hungary. Pannonian (Late Miocene-Pliocene) is usually considered as a post-rift calm period; however, there are many places that abound in thrust faulted, folded Pannonian strata. The Sava Folds in Croatia and Slovenia are a type example, but similar folds do exist in S Hungary (MÁRTON et al., 2002; SACCHI et al., 1999). Some unconformities suggest a Pliocene age of inversion. Around southern inselbergs (Mecsek-Villány; Požega, Papuk, Bilogora) Pannonian is overthrusted by older sediments. Some of these are documented by wells. There may be indications for as young inversion as Quaternary in the same zones (GRENERCZY et al., 2000).

The reasons for this vivid activity of inversion can be many. The earlier inversion-thrusting is very probably related to the opposite rotation of two major constituents of the Intra-Pannonian substrate: the Alpaca and the Tisza-Dacia elements (CSONTOS & NAGYMAROSY, 1998). The late inversion period might be mostly controlled by the northern advance of the Adriatic promontory, or the counter-clockwise rotation of the Dinarides or both (MÁRTON et al., 2002; TOMLJENOVIĆ & CSONTOS, 2001). A secondary reason might be provided by lithospheric scale buckling and/or isostasy (BADA et al., 2001; HORVÁTH & CLOETINGH, 1996).

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CERNIKIAN – A NEW PLIO-PLEISTOCENE REGIONAL STAGE OF THE SOUTHERN PANNONIAN BASIN

Oleg Mandic[1,*], Tomislav Kurečić[2], Thomas A. Neubauer[3] & Mathias Harzhauser[1]

INVITED LECTURER

*[1] Geological-Palaeontological Department, Natural History Museum Vienna, Burgring 7, 1010 Wien, Austria **

[2] Croatian Geological Survey, Sachsova 2, 10000 Zagreb, Croatia

[3] Department of Animal Ecology & Systematics, Justus Liebig University, Heinrich-Buff-Ring 26-32 IFZ, 35392 Giessen

*corresponding author: oleg.mandic@nhm-wien.ac.at

The Pliocene to early Pleistocene *Viviparus* beds represent the topmost tectonostratigraphic megacycle of the southern Pannonian Basin. As demonstrated by seismic profiles from northern Croatia, they overlie transgressively the Lake Pannon brackish-water deposits and represent a fully independent sequence stratigraphic unit. Yet, their stratigraphic independence was not consequently approved by the regional chronostratigraphic classification. They were attributed either to uppermost Pannonian or to Dacian and Romanian stages of the Paratethys regional stratigraphic scheme. Yet, whereas the first stage is confined to the duration of the Lake Pannon, the latter two are constituents of the Dacian Basin chronostratigraphic classification, proved to be asynchronous with the *Viviparus* beds.

We recommend therefore the usage of a newly introduced regional stage Cernikian (MANDIC et al., 2015), constrained to the depositional cycle of the *Viviparus* beds. The latter reflects deposition of the freshwater Lake Slavonia and is bounded by discrete compressional events from the preceding Pannonian and the succeeding Pleistocene depositional intervals. The stage name derives from a type area located in NE Croatian municipality Cernik. The stage is threefold; the substage correlation is facilitated by the strongly radiating *Viviparus* lineages, delivering backbone for a biostratigraphic zonation. Hence, the Lower Cernikian correlates to *V. neumayri* and *V. kochanskyae* zones; the Middle Cernikian to *V. bifarcinatus*, *V. stricturatus* and *V. nothus* zones; and the Upper Cernikian to *V. sturi*, *V. hoernesi*, *V. zelebori* and *V. vukotinovici* zones. The boundary stratotype, located NE of Cernik displays Pannonian sand with cardiid bivalves overlain by Cernikian clay bearing *Viviparus neumayri*. The most instructive section, showing a complete succession of the *Viviparus* beds, is represented by the Gojlo antiform E of Kutina (NE Croatia). There, the 900-m-thick Cernikian interval is composed largely by greenish clay and fine-sand bearing abundant viviparids. The 200-m-thick Lower Cernikian and the 600-m-thick Upper Cernikian interval contain 0.1 to 2-m-thick coal seams.

Although representing an isolated lake environment, at least temporary southward outflow from the Pannonian Basin existed, allowing some species to migrate to the Dacian Basin. The partial faunal overlap facilitates a rough calibration of the Cernikian biostratigraphy to the Dacian and Romanian stages based on shared *Viviparus* zonal markers. It further allows an indirect correlation to the Geological Time Scale using the current bio-magnetostratigraphic age model for the Dacian Basin. According to this correlation, the Cernikian spans the interval from 4.5 Ma to 2.0 Ma. The lower boundary of the Middle Cernikian is correlated to 4.2 Ma, the base of the Upper Cernikian corresponds to 3.3 Ma, approximately coinciding with the onset of the Pliocene Climate Optimum (PCO). The period between 4.3 and 2.7 Ma represents a generally warm phase, culminating between 3.3 and 2.9 Ma, when polar temperatures increased by up to 10°C. The increase of shell sculpture in lineages of the Lake Slavonia viviparids coincides with that warming trend. In contrast, the *V. vukotinovici* zone succeeding the PCO event shows retreat of weakly sculptured phenotypes.

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AMAZING BIODIVERSITY OF MIOCENE "REEFS"

Jasenka Sremac

INVITED LECTURER

Department of Geology, Faculty of Science, University of Zagreb, Horvatovac 102 a, Zagreb, Croatia

jasenka.sremac@geol.pmf.hr

During the Middle Miocene a number of bioconstructions developed along the shelves of the Paratethys Sea (RIEGL & PILLER, 2000, HARZHAUSER & PILLER, 2007; SREMAC et al., 2016). Heterogeneity of carbonate-producing biota and architecture of boundstone bodies reflect the complex tectonic and climatic history, as well as the changes in seawater chemistry. Build-ups are sometimes preserved in situ, but in many cases we recognize their biodiversity from fragments in the surrounding bioclastic deposits.

Badenian stage is characterized with the climax of the Paratethyan carbonate production. Early Badenian deposits comprise fairly diverse reefs, including the coral patch-reefs, particularly in southern Paratethyan basins (HARZHAUSER & PILLER, 2007).

Red algae are important bioconstructors throughout the Badenian, but their acme is linked with the second Badenian transgressive cycle, particularly in western parts of the Central Paratethys (HARZHAUSER & PILLER, 2007, SREMAC et al., 2016). They occur as free-living rhodoliths or attached, within coralligenous hard bottom communities. Rhodolith beds are known as ecosystems of high biodiversity and act as important carbonate "factories". They generally indicate shallow waters (<150 m) subjected to episodic disturbance, or develop after the reef erosion, as seen in some modern habitats (PILLER & RASSER, 1996). In Pannonian Basin System they often occur at the base of Miocene transgression(s). Rhodolith-forming species originate from all three major coralline groups (Sporolithales, Corallinales and Hapalidiales). The same rhodalgal groups occur in coralligene assemblages, associated with abundant and diverse bryozoans and other benthic biota. Large oysters can form their own reefs which can occur since early phases of transgressive cycles (HARZHAUSER et al., 2016; SREMAC et al., 2016). On the contrary, bryopsidalean algae occur to a lesser extent, probably in sheltered bays (SREMAC et al., 2016).

During the late Badenian, algal-bryozoan-coral bioconstructions in northern parts of the Paratethys were replaced with algal-serpulid-vermetid "reefs" and/or coral carpets developing along detached islands (PISERA, 1996; HARZHAUSER & PILLER, 2007).

Badenian/Sarmatian turnover reflects the strongest biotic crisis of the Paratethys. Mixed carbonate-siliciclastic deposition is only sporadically represented with carbonate build-ups formed by polychaetes and bryozoans, common in the Carpathian fore-deep (PISERA, 1996; HARZHAUSER & PILLER, 2007).

During the late Sarmatian, following the shift from siliciclastic to carbonate deposition, a new type of build-ups dominated by nubeculariids and microbial crusts occured, representing the last reef-like structures before the final isolation and desalination of the Paratethys.

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ABSTRACTS

THE EARLIEST SYN-RIFT SEDIMENTS OF THE EASTERN PART OF THE CROATIAN PART OF THE PANNONIAN BASIN SYSTEM (CPBS)

Dijana Bigunac

INA d.d., Exploration sector, Av. V. Holjevca 10, Zagreb, Croatia

dijana.bigunac@ina.hr

Early Miocene sediments of Vukovar, Moslavačka gora and Prečec formations in Slavonsko – srijemska, Dravska and Savska depressions could be subdivided into several facies that are so far rarely recognized and described using well data. These sediments are interpreted as deposited in alluvial and lacustrine environments during Ottnangian and Karpatian.

DEEP-MARINE MOLLUSK ASSEMBLAGES IN MIDDLE MIOCENE (BADENIAN) DEPOSITS OF THE MEDVEDNICA MT., NORTHERN CROATIA – TODAY'S POINT OF VIEW

Marija Bošnjak[1,*], Jasenka Sremac[2] & Davor Vrsaljko[1]

[1] *Croatian Natural History Museum, Demetrova 1, Zagreb, Croatia* *

[2] *Department of Geology, Faculty of Science, University of Zagreb, Horvatovac 102 a, Zagreb, Croatia*

*corresponding author: marija.bosnjak@hpm.hr

Middle Miocene (Badenian) deposits of the Medvednica Mt., northern Croatia, have been studied since the beginning of the 20th century, and numerous mollusks were collected during the previous researches (e.g., GORJANOVIĆ-KRAMBERGER, 1908, KOCHANSKY, 1944). Collected malacofauna is housed at the Croatian Natural History Museum in Zagreb. Recent research of Badenian deposits in the central part of the Medvednica Mt., wider Čučerje area, yielded new deep-marine mollusks findings, and fulfilled the list of the previously recorded fauna (GORJANOVIĆ-KRAMBERGER, 1908, KOCHANSKY, 1944; KOCHANSKY-DEVIDÉ, 1957; BOŠNJAK et al., submitted).

The authors here describe two types of mollusk fauna: 1) benthic, represented by chemosymbiotic benthic bivalves: *Solemya doderleini* MAYER, 1861 and family Lucinidae J. FLEMING, 1828, and 2) planktic, comprising pteropods: *Limacina valvatina* (REUSS, 1867), *L. gramensis* (RASMUSSEN, 1968), *Clio fallauxi* (KITTL, 1886), *C. pedemontana* (MAYER, 1868) and *Vaginella austriaca* KITTL, 1886.

Few bivalve genera recorded from the investigated area: *Solemya* LAMARCK, 1818, *Lucinoma* DALL, 1901 and *Myrtea* TURTON, 1822, today may indicate seep sites. This chemosymbiotic bivalves are known as hosts of sulfur-oxidizing bacteria, and methane-oxidizing bacteria in lesser extent (TAYLOR & GLOVER, 2006; KIEL & PECKMANN, 2007). These fauna today live in chemosynthetic environments distributed from shallow waters to bathyal depths, and include habitats of hydrothermal vents, submarine caves with sulphur springs, cold seeps and oxygen-deprived environments (e.g., marine seagrass beds) (TAVIANI, 2014). Recent bivalves of the genus *Solemya* live in reduced environments, cold and vent seeps, and their fossil record indicates deep-sea reducing niches (TAVIANI et al., 2011; SATO et al., 2013). Family Lucinidae today represents the most species-rich and the most widespread bivalve family considering marine sulphide-rich habitats in cold seeps and marine sea grasses with chemosymbiots (TAYLOR & GLOVER, 2006 and references therein). Paleoenvironmental studies of specialized benthic mollusks from today's point of view give new insight on the possible habitats and specificities of environmental conditions in the investigated area.

Mollusk fauna from the central Mt. Medvednica Badenian deposits also comprises planktic gastropods belonging to five taxa: *Limacina valvatina*, *L. gramensis*, *Clio fallauxi*, *C. pedemontana* and *Vaginella austriaca* (GORJANOVIĆ-KRAMBERGER, 1908, KOCHANSKY, 1944; BOŠNJAK et al., submitted). Pteropods live today in worldwide oceans of tropic, temperate, cold and polar waters (e.g., JANSSEN & PEIJNENBURG, 2014). During the Badenian of the Central Paratethys, two pteropod horizons coinciding with marine transgressions can be recognized: Early-Middle Badenian marked by abundant *Vaginella austriaca* and sporadic *Clio* occurrences, and the Upper Badenian, *Limacina* horizon (RÖGL, 1998; BOHN-HAVAS & ZORN, 2002). Badenian pteropod assemblages provide correlation with other contemporaneous Central Paratethys records, and can contribute to the reconstruction of the possible fauna migration during Badenian marine transgressions.

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THE EARLY PANNONIAN (LATE MIOCENE) STRATIGRAPHIC RESEARCH OF THE TRANSYLVANIAN BASIN (ROMANIA): NEW BIOSTRATIGRAPHIC AND AUTHIGENIC $^{10}Be/^{9}Be$ ISOTOPIC DATA

Dániel Botka[1,*], Imre Magyar[2,3], Michal Šujan[4] & Régis Braucher[5]

[1] *Department of Palaeontology, Eötvös Loránd University, Budapest, Hungary**

[2] *MOL Hungarian Oil and Gas Plc., Budapest, Hungary*

[3] *MTA–MTM–ELTE Research Group for Paleontology, Budapest, Hungary*

[4] *Department of Geology and Paleontology, Comenius University, Bratislava, Slovakia*

[5] *Aix-Marseille Université, CNRS-IRD-Collège de France, CEREGE, Aix-en-Provence, France*

*corresponding author: botkadani@gmail.com

During the Late Miocene, an enormous and long-lived lake – Lake Pannon – with rich endemic fauna covered most of the intra-Carpathian realm. For a while, the water mass of the Transylvanian Basin was connected to Lake Pannon through the Sălaj area and/or the Mureş Valley (MAGYAR et al., 1999; NEUBAUER et al., 2016).

Today, the Pannonian sediments occur in a more or less contiguous area in the central, south-western and eastern part of the basin. After their deposition, exhumation and erosion started due to tectonic inversion, therefore the average thickness of the Pannonian sequence is only 300 m. The estimated age of these sediments is between 11.6 and 9.5 Ma (KRÉZSEK et al., 2010).

In the lack of a detailed and comprehensive treatise on the Pannonian fossils of the area, the accurate biostratigraphic resolution of this ca. 2 million years has not been developed so far (LUBENESCU, 1981). The widely outcropping Early Pannonian deposits offer an excellent opportunity for a modern investigation of the fauna and for exploring the changes that occurred at the beginning of the Pannonian. The rocks of similar age and their fauna are deeply buried in the Pannonian Basin and are mostly known from boreholes (e.g. SZÉLES, 1962).

Taxonomic determination and revision of Pannonian brackish-water gastropods and bivalves were carried out from 72 localities. The material came from our own collection (12 localities) and from collections of the Geological and Geophysical Institute of Hungary (59 localities), the Hungarian Natural History Museum, Budapest (6 localities), and the Palaeontological Collection of the Department of Palaeontology of the Eötvös Loránd University (2 localities). Altogether 3124 specimens were determined so far, representing 17 genera and 56 species. There are 75 mollusc taxa in the material, including 3 probably new species.

Based on faunal composition and sedimentological characteristics of the localities, shallow-water (littoral) and deep-water (sublittoral and profundal) associations were separated. The shallow-water outcrops are mainly on the basin-margin, while the deep-water ones are rather located in the central part of the basin. We found just one fauna containing *Congeria czjzeki* – a characteristic species of sublittoral assemblages – at the locality of Lopadea Veche. We hypothesize that 9.5-9 million years ago the Transylvanian Basin became isolated from the Pannonian Basin, as suggested by the appearance of new endemic taxa, and evolved as an independent lake.

Authigenic $^{10}Be/^{9}Be$ isotopic dating method was applied on 7 samples from 4 localities. The tentative results were combined with the biostratigraphic data, thus in case of the deep-water sediments, 2 biozones and 4 subzones ("*Lymnocardium*" *praeponticum* – *Gyraulus vrapceanus* assemblage zone and *Congeria banatica* assemblage zone with *Radix croatica*, *Velutinopsis velutina*, *Undulotheca nobilis* and *U. rotundata* lineage subzones) were established.

The research was funded by the Hungarian National Research, Development and Innovation Office (NKFIH – 116618).

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BIOERODED ROCKY SHORES AND CALCAREOUS PLANKTON STRATIGRAPHY OF THE MIDDLE MIOCENE (BADENIAN) TRANSGRESSIVE SUCCESSIONS IN THE NORTH CROATIAN BASIN (CENTRAL PARATETHYS)

Mihovil Brlek[1,*], Stjepan Ćorić[2], Ljiljana Iveša[3], Ana Santos[4], Monika Špišić[1], Vlatko Brčić[1], Massimo Devescovi[3], Ivan Mišur[1], Radovan Avanić[1] & Markes E. Johnson[5]

[1] *Croatian Geological Survey, Department of Geology, Sachsova 2, HR-10000 Zagreb, Croatia*

[2] *Geological Survey of Austria, Neulingg. 38, A-1030 Wien, Austria*

[3] *Ruđer Bošković Institute, Center for Marine Research, G. Paliaga 5, 52210 Rovinj, Croatia*

[4] *Universidad de Granada, Facultad de Ciencias, Dept. Estratigrafía y Paleontología, Campus de Fuentenueva s/n, 18002 Granada, Spain*

[5] *Geosciences Department, Williams College, Williamstown, MA 01267, U.S.A*

*corresponding author: mihovil.brlek@hgi-cgs.hr

Mesozoic (Upper Cretaceous and Triassic) basement limestone lithoclasts occurring in basal conglomerates (overlain by rhodolith-bearing and *maërl* deposits) of the Middle Miocene transgressive deepening-upward successions of northeast Mt. Medvednica (North Croatian Basin, Central Paratethys; BRLEK et al., 2016) show abundant *Gastrochaenolites* and *Entobia* borings (represented by an *in situ* rocky substrate community of bivalves and sponges, respectively), with *Gastrochaenolites* being the dominant ichnogenus and together with *Entobia* often occurring on all sides of limestone clasts. *Gastrochaenolites torpedo* and *Gastrochaenolites lapidicus* are the two most commonly recorded ichnospecies of bivalve borings (with possible occurrence of *G. dijugus*, *G. cluniformis*, and *G. orbicularis*). *Gastrochaenolites-Entobia* ichnofossil assemblage related to the *Entobia* subichnofacies and in turn assignable to the *Trypanites* Ichnofacies, is very typical of Neogene rocky shores (DE GIBERT et al., 2012). This ichnoassociation characterizes littoral rockground environments indicating wave-cut platforms and marine flooding surfaces (transgressive surfaces) with a low or null rate of sedimentation (BROMLEY & ASGAARD, 1993). Actualistic comparison was made in order to make more accurate palaeoecological and palaeoenvironmental interpretations (based on e.g., ecology of possible tracemakers, as well as recorded trace fossil assemblages, orientation, preservation, and succession of ichnocoenosis with possible cross-cutting relationships) of the basal Middle Miocene conglomerates. Modern Northern Adriatic rocky coast endoliths (*Lithophaga lithophaga*, *Rocellaria/Gastrochaena dubia*, clinoid sponges) and their bioerosion trace fossils (*Gastrochaenolites torpedo*, *Gastrochaenolites dijugus*, ? *G. lapidicus*, *Entobia* sp.) were analysed from breakwater limestone boulders of the west Istrian coast (DEVESCOVI & IVEŠA, 2008).

The Badenian, regarded as Middle Miocene regional stage of the Central Paratethys, has recently been subdivided by HOHENEGGER et al. (2014) based on paleoclimatic events (e.g., MMCO and MMCT), sea-level changes and biostratigraphic data. According to ĆORIĆ et al. (2009), the initial Middle Miocene marine flooding of the North Croatian Basin corresponds to Middle Badenian transgressive pulse (NN5 Zone, TB 2.4) of the Central Paratethys (HOHENEGGER et al., 2014). The co-occurrence of calcareous nannoplankton *Sphenolithus heteromorphus* and *Helicosphaera waltrans* (with absence of *Helicosphaera ampliaperta*) in some marl intervals (which represent the uppermost part of the Middle Miocene trangressive deepening-upward successions on northeast Mt. Medvednica) analysed here, points to the lower part of nannoplankton Zone NN5. HOHENEGGER et al. (2014) correlated this part of NN5 with *Orbulina suturalis* Plankton Zone of the Middle Badenian (TB 2.4 – main Badenian transgressive pulse of the Central Paratethys), which is also supported by the recorded co-occurrence of planktonic foraminifera *Orbulina suturalis* and *Praeorbulina glomerosa circularis*. Somewhat younger age (the upper part of NN5 Zone) of some successions is suggested by the occurence of *Orbulina universa*, supported also by recorded nannoplankton assemblage with *Reticulfenestra minuta*, *Coccolithus pelagicus* and *Helicosphaera carteri*. Besides the Badenian transgressive pulse(s) of the Central Paratethys being the probable cause for the development of Mt. Medvednica transgressive successions, possible local tectonic influence must also be taken in consideration due to possible age difference and stratigraphic position of closely spaced Mt. Medvednica outcrops on the Badenian sea-level curve.

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LITHOSTRATIGRAPHIC SUBDIVISION OF LONJA FORMATION (APPROXIMATE PLIOCENE, PLEISTOCENE AND HOLOCENE) BASED ON SUBSURFACE AND SURFACE DATA

Marko Cvetković[1,*], Valentina Hajek-Tadesse[2] & Koraljka Bakrač[2]

[1] University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering, Pierottijeva 6, 10 000 Zagreb, Croatia

[2] Croatian Geological Survey, Sachsova 2, 10 000 Zagreb, Croatia

*corresponding author: marko.cvetkovic@rgn.hr

Entire subsurface clastic (Neogene and Quaternary) infill volume of the Sava Depression has been divided into lithostratigraphic units in the rank of formations while only some were subdivided into the rank of members (PLETIKAPIĆ, 1969; ŠIMON, 1980). This kind of approach was influenced by the Petroleum geology importance of determined formations, hence member subdivision and detailed analysis were only performed in the hydrocarbon bearing ones (e.g. Ivanić-Grad, Kloštar Ivanić and Široko Polje formation).

Lonja formation presents the youngest most part of the Pannonian Basin infill and roughly relates to sediments of Pliocene, Pleistocene and Holocene age. As a formation of lesser importance, it was not analysed in detail and subdivided. As in more modern hydrocarbon explorations, an importance for gas accumulations arose, it became more interesting. An integrated analysis comprised of available outcrop sampling and analysis regarding lithological composition, heavy mineral fraction, micro and macro-fossil determination along with palynological analysis. Surface to subsurface data correlation was performed based on macrofossil (primarily *Viviparus* molluscs), microfossil (ostracoda) assemblage along with their approximate position to the subsurface model. In the next step, surface data was correlated with the available subsurface data (Well logs, rock cutting description, scarce seismic) resulting in subdivision of the Lonja formation into six members (Figure 1.), primarily on well log analysis.

Paleo-reconstruction of the environments that followed the shallowing of the Pannonian Lake after Miocene (LUČIĆ et al., 2001; MANDIĆ et al., 2015) was performed based on well log and surface data. As the result of the analysis, a difference was noted in the clastic material assemblage in contrast to Uppermost Miocene (*Rhomboidea* beds). Heavy mineral fraction lacked less resistant minerals in the base part of the formation (Hrastilnica, Ravneš and base part of the Vrbak member) suggest either long sediment transport or resedimentation of older clastic strata.

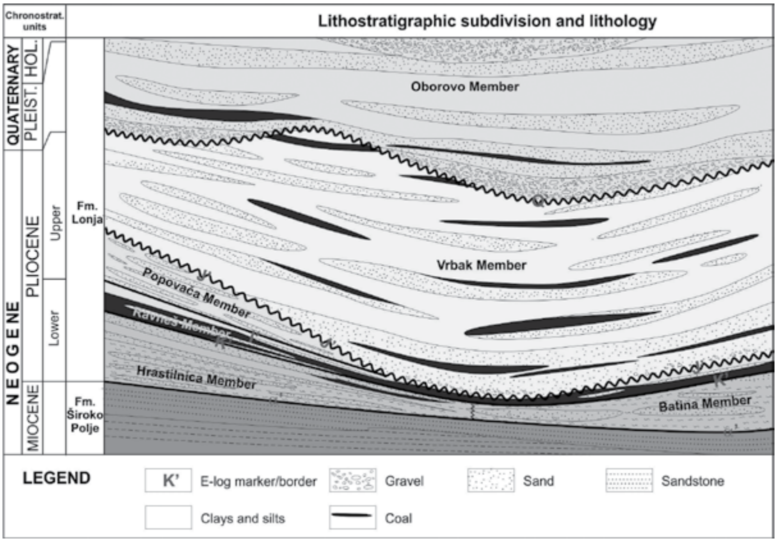

Figure 1. Lithostratigraphic subdivision of the Lonja Formation (CVETKOVIĆ, 2013; 2016).

An increase in the content of the less resistant minerals in heavy fraction in the uppermost part of the Vrbak member, could possibly relate to the increased uplift of today's Moslavačka gora Mt. More specifically, when the Upper Miocene sandstones and marls deposited on Moslavačka gora Mt. were eroded, material for the infill was mixed together with the weathered magmatic and metamorphic complex. Possibility of re-sedimentation of the Pliocene strata was also confirmed with the finding of re-sedimented Miocene brackish dynociste in *Viviparus* abundant beds.

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CHANGES IN MIDDLE/UPPER MIOCENE CALCAREOUS NANNOPLANKTON ASSEMBLAGES (CENTRAL PARATETHYS; NAŠICE; CROATIA) – PALEOECOLOGY AND STRATIGRAPHY

Stjepan Ćorić[1,*], Marijan Kovačić[2], Željko Bortek[2], Frane Marković[2] & Davor Vrsaljko[4]

[1] *Geological Survey of Austria, Neulinggasse 38, A-1030 Vienna, Austria*

[2] *University of Zagreb, Faculty of Science, Department of Geology, Horvatovac 95, 10 000 Zagreb, Croatia*

[3] *Našicecement d.d., Tajnovac 1, 31 500 Našice, Croatia*

[4] *Croatian Natural History Museum, Demetrova 1, 10 000 Zagreb, Croatia*

*corresponding author: stjepan.coric@geologie.ac.at

Calcareous nannofossils from the Badenian, Sarmatian and Pannonian sediments were investigated from three localities in the area of the cement factory "Našicecement": borehole B-1, Bukova Glava and Vranović.

Samples from borehole B-1 contain upper Badenian high diversified nannofossil assemblages with common *Coccolithus pelagicus* accompanied by reticuloefenstrids (*R. minuta*, *R. haqi*, *R. pseudoumbilica*), *Helicosphaera carteri*, *H. walbersdorfensis, Sphenolithus moriformis* etc. pointing to the full marine, euthrophic paleoconditions. The absence of *S. heteromorphus* allows the attribution into NN6 nannoplankton Zone.

Samples from Badenian/Sarmatian boundary from the locality Bukova Glava contains rich nannoplankton assemblage with bloom of *Calcidiscus pataecus*. This event, caused probably by suddenly changes in water salinity and chemistry on Badenian/Sarmatian boundary, was described from Slovenia, Bosnia and Hercegovina and Romania. Assemblages with blooms of *Cd. pataecus* occur directly above Badenian/Sarmatian boundary seems to be synchronous across the Central Paratethys and can be an useful marker to trace this boundary.

Sarmatian and Pannonian sediments from locality Vranović, was sampled from 18m thick section subdivided into 51 lithological units. Sediments are grouped into three facies: horizontaly laminated marls, marly limestones and limestones and tuff layer. In total 140 samples from this section were quantitative analysed. Five horizons with common diatoms and silicoflagelates occur in horizontally laminated marls. Limestones and whitish laminae within laminated marls with > 95 $CaCO_3$ contain blooms of ascidian spiculae. Within the Sarmatian part of the profile following units can be distinguished (from the bottom to the top):

– low diversity assemblage with dominance of *R. pseoudoumbilica* and *Calcidiscus leptoporus* accompanied by *Coronosphaera mediterranea* and small reticulofenestrids;
– assemblage dominated by *Cd. leptoporus* and *Cor. mediterranea*;
– assemblage with more than 90% of *Cor. mediterranea;*
– sediments containing high percentages of small reticulofenestrids, *Braarudosphaera bigelowii* and *Cor. mediterranea* with occasional blooms of *S. moriformis*;
– assemblages dominated by small reticulofenestrids and *Cor. mediterranea*.

Uppermost part of the section belongs to the Pannonian and contains abundant ascidian spiculae. Two sections from Vranović locality (approximately 80m thickness) described by PAVELIĆ et al. (2003) contain horizons with blooms of ascidian spiculae, *Isolithus* spp., and *Noelaerhabdus* spp.

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COMPARISON OF EARLY MIOCENE FLORA FROM LOCALITIES PLANINA AND POLJANSKA IN NORTHERN CROATIA

Tamara Đerek* & Sanja Japundžić

Croatian Natural History Museum, Demetrova 3, 10 000 Zagreb, Croatia

*corresponding author: tamara.derek@hpm.hr

Numerous specimens of Early Miocene macrofloral remains are stored in the Croatian Natural History Museum. Fossils has been collected from two localities: Planina and Poljanska, mainly by the curators of the Museum during field works since 19th century.

Locality Planina is situated on southeastern part of Medvednica Mt. near Zagreb. The plants have been preserved in marly sediments. The collection consist of almost 300 specimens. First detailed study of this flora was taken by Polić in 1935. Plant remains are mostly fragmentary preserved as impressions of leaves, fruits, seeds and branches. As a whole, the palaeoflora from this locality indicate a warm, subtropical climate. The most abundant species is *Myrica lignitum* (Unger) Saporta. Common elements are also Lauraceae, especially *Daphnogene*, and legume-type taxa. Species of *Pinus* are dominant conifers. The compositions of the flora suggest prevailing of subtropical elements over the arcto-terciary elements which are sparse.

Poljanska locality is situated on south slopes of Papuk Mt., about 20 km north-east from the city of Požega in Slavonia. The plant remains were collected in the last ten years and untill now collection has almost 200 specimens, mostly leaves which are generally well preserved. Most of the material consists of leaf imprints, but there are also some fruit/seed and branches. They were found in thin-layered marlstones. Floral assemblage suggest subtropical climate. The dominant species here is also *Myrica lignitum* (Unger) Saporta. Legume-type taxa are present in great number. *Pinus* and *Daphnogene* species are quite rare. Palaeotropical elements are prevailing over the arcto-terciary elements, but number of arcto-terciary elements are here in slightly higher amount.

Fossil plant assemblages on both sites show great similarity. The Planina collection include more species than Poljanska collection but shares most taxa. Paleosubtropical element prevails while the arcto-tertiary genera make only a fragment of the flora in both sites. Leaf size varies between notophyllous and micro-phyllous classes.

According to composition of both paleofloras it could be concluded that the zonation of flora was quite distinguishable with different types of habitats.

The most abundant species on both localities is *Myrica lignitum* (Unger) Saporta which is characteristic of subtropical areas and requires a moist habitat along the coast, suggesting swampy environments. From common species follows *Laurus and Daphnogene* which together with *Myrica* represent a group of plants that existed in flooded areas surrounding palaeolakes.

Further away from the coast rich vegetation with *Eucalyptus oceanica* Unger*, Zizyphus paradisiacus* Unger, *Andromeda protogea* Unger and various legume-type taxa existed, in conditions of subtropical dry climate.

Upland environments, away from the cost, were covered with *Pinus* species and *Quercus lonchitiis* Unger.

Changes in the floristic composition could be due to insufficient exploration of localities and further investigations will probably show more similarity between these two sites.

THE PALEOENVIRONMENTAL CHANGES DURING THE KONKIAN AND DEFINITION OF THE KONKIAN/SARMATIAN BOUNDARY IN THE EASTERN PARATETHYS

Larisa Golovina[1,*], Yuliia Vernyhorova[2], Sergey Popov[3] & Irina Goncharova[3]

[1] *Geological Institute RAS, Moscow, Russia*
[2] *Institute of Geological Sciences, National Academy of Sciences of Ukraine, Ukraine*
[3] *Borissiak Paleontological Institute RAS, Moscow*

*corresponding author: golovinal@mail.ru

The Konkian stratotype section located on the Konka River near Veselyanka Village (Ukraine). However the stratotype section lack of a complete succession and includes only upper Konkian – Veselyanka Beds. It was the cause to various, often conflicting, views interpretations of the Konkian regiostage and its boundaries. The complete and continuous sequence of Karaganian–Konkian deposits (from the core of the anticlinal fold Zelensky Hill to Cape Panagia, Taman Peninsula) has provided the data improving the volume and boundaries of the Konkian regiostage (GOLOVINA et al., 2004; POPOV et al., 2016).

Our biostratigraphical results are key to understand the paleoenvironmental changes in the Konkian basin in its open part. According to micropaleontological data three subdivisions (***a***, ***b***, ***c***) are corresponded to significant reorganization of the hydrological conditions in the Konkian basin and correlated with the Kartvelian, Sartaganian and Veselyankian.

The first subdivision ***a*** (Kartvelian) is characterized by appearance of nannoplankton accompanied by planktonic foraminifera of *Globigerina* genus and marine benthic foraminifera genera: *Discorbis*, *Cassidulina*, *Nodobaculariella*, *Articulina*, *Reussella*. The nannoplankton assemblage is rather poor and does not contain zonal species, but its taxonomic composition suggests that it should be correlates with the assemblage of nonstratified NN6–NN7 zones of the scale proposed by MARTINI (1971). That is corroborated by single specimens of *Discoaster* aff. *kugleri.* This subdivision marks the beginning of a new marine cycle.

The second subdivision ***b*** (Sartaganian) contains abundant nannoplankton and foraminiferal assemblages. Both planktonic and benthic groups show quantitative and qualitative variations in composition, most likely reflecting pulsating marine influxes (fluctuations of salinity, temperature and nutrient input), reflecting an unstable marine environment of Konkian basin. The significant environmental changes took place during the upper part of this subdivision, where the rapid dominance of monospecific coccoliths *Reticulofenestra pseudoumbilicus* was established. Thus, the association of nannoplankton reflect a environmental changes in the surface waters of the basin. At the same time, the benthic microfauna continues to be rich and diverse. In this part of the section are found characteristic Konkian mollusks: *Timoclea (Parvivenus) konkensis*, *Alveinus nitidus*, *Modiolus* sp.

The third subdivision ***c*** (Veselyankian) is characterized by poor benthic euryhaline foraminiferal assemblage and is showed various blooms of *Reticulofenestra pseudoumbilicus* (VERNIGOROVA et al., 2006).

The Konkian-Sarmatian boundary is determined by the onset of the typical Sarmatian mollusks and benthic foraminifera assemblages, just following the final bloom of *Reticulofenestra pseudoumbilicus* at top of substage ***c*** (Veselyankian).

New paleomagnetic data allow to correlate Konkian with the Late Badenian (Kosovian) of Central Paratethis (PALCU et al., in press).

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TECTONIC EVOLUTION OF THE DRAVA DEPRESSION AND ITS IMPACT ON SOURCE ROCK DISTRIBUTION , HYDROCARBON GENERATION AND MIGRATION

Andrea Gruić Jukić[1,*], Tamara Troskot-Čorbić[2] & Damir Takač[1]

[1] *INA – Industrija nafte d.d., Exploration sector, Geology & Geophysics Department, Av. Većeslava Holjevca 10, Zagreb, Croatia*

[2] *INA – Industrija nafte d.d., Exploration sector, Rock & Fluid Analysis Department, Lovinčićeva 4, Zagreb, Croatia*

*corresponding author: andrea.gruicjukic@ina.hr

Drava depression is located in the southwestern margin of the Pannonian Basin. According to MALVIĆ & VELIĆ (2011) and MATOŠ (2014), Neogene and Quaternary tectonics in the Drava depression are very complex, due to two phases of transtension (Badenian and Late Pannonian-Early Pontian) and two of transpression (Sarmatian-Early Pannonian and Late Pontian-recent). These tectonic events had huge impact on lithology causing heterogeneities, laterally and vertically, that are particularly important in source rock distribution. There are 20 oil, gas and condensate fields in Drava depression which are according to geochemistry data genetically correlated to source rocks - marls, siltstones and mudstones of Badenian to Panonnian and Lower Miocene age (BARIĆ et al., 1998). The aim of this paper is to assess the impact of different tectonic manifestation on source rock distribution and main processes that caused hydrocarbon accumulation - maturation, generation and migration. Basin modelling can address key questions related to timing of maturation and migration by considering geologically plausible range of kerogen or organic facies in different thermal history scenarios and tectonic models.

Source rocks are modelled in clusters according to affiliation to certain tectonic blocks. Quantitative information about thermal subsidence and tectonic vertical movements, heat flow (HF), paleo-water depth (PWD) and sediment water interface temperature (SWIT) changes are decisive because they vary either in time or laterally, having a great impact on source rock maturation (CSIZMEG et al., 2011; HORVATH et al., 1986; LENKEY et al., 2002).

As a result, transformation ratio and maturity maps were compiled for Lower Miocene, Badenian and Pannonian source rocks, revealing large differences in present-day thermal maturity within the Drava depression, also showing differences in time of generation and expulsion up to 4 Ma. 1D models indicate the influence of kerogen type, heat flow history, subsidence and uplift variations on source rock maturation, hydrocarbon generation, timing of expulsion and migration. Based on stable carbon isotope analysis (CHUNG et al., 1988; SCHOELL, 1983) hydrocarbons are positively correlated to source rock, suggesting both upward and sidelong migrations from all effective depocenters.

Timeline of events is an important factor in hydrocarbon exploration process. For a petroleum system to function formation of traps and seals must precede hydrocarbon expulsion and migration routes should be established (CORVER et al., 2009). Results confirm that basin models contribute to the synthesis of geological, seismic and geochemical data consistently. By defining time of parameters for petroleum occurrence, these models increase exploration efficiency.

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PETROGRAPHIC ANALYSIS OF MIOCENE SEDIMENTARY ROCKS IN SLOVENJ GRADEC BASIN

Kristina Ivančič[1,*], Mirka Trajanova[1], Dragomir Skaberne[1] & Andrej Šmuc[2]

[1] *Geološki zavod Slovenije, Dimičeva ulica 14, 1000 Ljubljana, Slovenia*

[2] *Oddelek za geologijo, Aškerčeva 12, 1000 Ljubljana, Slovenia*

*corresponding author: Kristina.ivancic@geo-zs.si

The Slovenj Gradec Basin (SGB) is a NW–SE trending basin located between Northern Karavanke Mts. on the south-west and the Pohorje range on the east. The basin is filled with syntectonic Miocene sediments (MIOČ & ŽNIDARČIČ, 1977; MIOČ, 1978). Their succession, however, is poorly known and lithostratigraphy undivided.

The area of SGB was a part of paleogeographic unit of Pannonian basin in Miocene. Pannonian basin represented heterogeneous Miocene sedimentation space of the Central Paratethys. Two major sub-basins of the Pannonian basin meet in eastern Slovenia: the Mura-Zala and the Styrian basins (FODOR et al., 2002). The SGB represents a small marginal sedimentation space located broadly somewhere between the two basins.

Six sections were recorded in the area of SGB from Velunja valley in the south to Podgorje in the north (IVANČIČ et al., 2015). Analyses were carried out mostly on fine- to coarse- grained sandstones present in the section, and some on conglomerates and siltstones. Out of 139 samples, 20 representative thin-sections were chosen for quantitative mineral composition of the sandstones, determined by point counting of minimum 300 points per each thin section, using Dickinson method (DICKINSON & SUCZEK, 1979).

Sedimentation in SGB stared with coarse grained material representing conglomerate beds. Upward, they are frequently alternating with beds of sandy conglomerates, sandstones, pebbly sandstones, siltstone, and marlstones. Pebbles in conglomerate are mostly of quartz, and carbonate and metamorphic rocks, while pebbles of igneous rocks are rare. Locally, pebbles are imbricated; they reach sizes up to 30 cm. Sandstone, siltstone and marlstone are bedded, rarely laminated, and in places contain plant remains and bioturbations. Petrographically, sandstones are prevailingly fine- to coarse-grained, poorly to moderately sorted and the grains are mostly angular to subrounded. In some samples oblong grains are oriented parallel to bedding. They are composed mainly of lithic fragments of carbonate (limestone and dolostone) and metamorphic rocks (quartzite, schists, polycrystalline metamorphic quartz, phyllite), and chert. Fragments of phyllosilicates (muscovite, biotite and chlorite) are also frequent. Accessory minerals (tourmaline, garnet, apatite, zircon, rutile, titanite and opaque minerals) and alocheme components (glauconite, foramenifera, rodophyta, echinoderm plates, bryozoan, red algae, and brachiopods) are rare. Based on marine biota, we divided marine and terrestrial environment. Modal composition of sandstones is presented in QFL and QmFLt diagrams. They show that sediments form SGB originated from recycled orogen. Prevalence of metamorphic grains in most of the samples indicate provenance of the sediments from the structural unit of Eastern Alps. In relatively short time 3 different depositional sequences occur, which indicate frequent alternation of marine and non-marine environment in marginal parts of the SGB, where sea level oscillations left clearer trace.

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LITHOFACIES CLASSIFICATION OF UPPER MIOCENE SEDIMENTS IN THE SAVA BASIN FROM WELL LOG AND CORE DATA USING PETROPHYSICAL SOFTWARE AND INDEXED PROBABILIZED SELF ORGANIZED MAP

Ema Jakupec* & Željka Marić-Đureković

INA d.d. – Industrija nafte, d.d. Avenija Većeslava Holjevca 10, 10020 Zagreb

*corresponding author: ema.jakupec@ina.hr

Drilling wells has a great value in many different aspects. Beside its primary role to drill the reservoirs and to produce oil and gas it gives us a lot of geological information which could not be acquired differently. The only way to get the insight information about the drilled formations and their lithological properties is through well log interpretation. Conventional well logs provide all the necessary information about the basic features of rocks. They are used for correlation between wells and to determine lithology, porosity and fluid saturations. For better understanding of reservoirs as well as their geological properties different types of high resolution borehole image logs are used. They have higher resolution and can detect small changes that are beneath the resolving thickness of the conventional logging tools. These logs provide important information for better understanding of sedimentological, structural and petrophysical properties of reservoir rocks. However, in order to correctly determine lithology from well logs, core data is used. Utilizing all available data form well logs and cores and it is possible to make lithofacies classification of drilled formations.

Process of lithofacies classification of five wells from small field in Sava basin is described in this article. Conventional well logs are used for general lithology determination and for well to well correlation. Core data was used alongside log data to reduce the uncertainty and to correctly determine rock properties. Image logs interpretation from three wells gave us more detailed insight into drilled formations. Different characteristics such as sedimentary features, layering, fining upward, erosional structures and in situ stress indicators were observed. Combining all available data, detailed lithofacies classification of Upper Miocene sediments was made. The major lithofacies identified are: a) sandstone (massive, parallel and cross-bedded), b) marls (limy and silty) and c) heterolithics (thin alteration of sand/silt/marl). Vertical association of these facies, azimuthal variation in dip pattern and image texture led to identification of different architectural elements of the depositional system: a) sandy channel-lobes complex, b) non channel heterolithics and c) massive marls.

Besides visual inspection of conventional and image logs, automatic electrofacies classification was made using IPSOM which identifies patterns/groups in data using the principles of "self-organizing map" (SOM). IPSOM is based on the rule that each facies is characterized by certain log response. The output is classification curve which is additional help when lithofacies classification is made.

DOLPHIN REMAINS (CETACEA: ODONTOCETI) FROM THE MIDDLE MIOCENE (SARMATIAN) DEPOSITS NEAR NAŠICE, CROATIA

Sanja Japundžić[1,*], Davor Vrsaljko[1], Željko Bortek[2], Dražen Japundžić[1], Jasenka Sremac[3] & Marija Bošnjak[1]

[1] *Croatian Natural History Museum, Demetrova 1, 10000 Zagreb, Croatia*
[2] *Našicecement d.d., Tajnovac 1, 31500 Našice, Croatia*
[3] *Department of Geology, Faculty of Science, University of Zagreb, Horvatovac 102a, 10000 Zagreb, Croatia*

*corresponding author: sanja.japundzic@hpm.hr

Dolphin remains were found in an active cement quarry near Našice during the field work in 2016 (Figure 1). The remains were scatered in few blocks of sediment extracted by exploitation from the nearby outcrops. Bones are embedded in finely laminated marls comprising mollusks *Ervilia dissita dissita* (EICHWALD), *Cardium* (*Cerastoderma*) *vindobonense* (PARTSCH & LASKAREV) and *Cardium* (*Cerastoderma*) *gleichenbergense* (PAPP). These marls were deposited in a lagoonar marine environment with reduced salinity during the Sarmatian (KOVAČIĆ et al., 2015).

Sediment blocks with dolphin remains were shortly transported downslope from an undisturbed sedimentary sequence. Rather fragile incomplete right scapula, 18 vertebrae and few more or less completed ribs, probably belonged to a single animal. Three smaller vertebrae from the same sediment block point to another, juvenile specimen, since the epyphyses of the vertebrae are not fused. Two simple, conical teeth of different size were additionally found in the same block. The smaller tooth is complete, while the larger is partially preserved, missing a part of the root. Based on the anatomy and size of the skeletal remains they probably belong to a highly diverse and widely distributed polyphyletic assemblage Kentriodontidae, subfamily Kentridontinae. This subfamily includes small to medium sized dolphins, and it is mostly well known from the Middle or early Upper Miocene deposits in Europe and North America (MARX et al., 2016).

Figure 1. Part of the fossil dolphin's remains from Našice. Scale bar 1 cm.

According to the collected skeletal parts, we can conclude that remains belong to at least two animals, one adult and one young.

Similar remains of Kentridontidae were described from a sand quarry Vranić near Požega (VRSALJKO et al., 2010), but the bones from that locality were fragmented and eroded during the redeposition, and could not be assigned to a specific primary outcrop.

The remains from Našice are therefore more important since they are the first *in situ* findings of kentriodontid dolphins in Croatia.

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FIRST FINDING OF THE SARMATIAN FISH ON THE DILJ GORA MT.

Sanja Japundžić[1,*], Ivana Maruščak[2] & Dražen Japundžić[1]

[1] *Croatian Natural History Museum, Demetrova 1, 10000 Zagreb, Croatia*
[2] *The Brodsko Posavlje Museum, Starčevićeva 40, 35000 Slavonski Brod, Croatia*

*corresponding author: sanja.japundzic@hpm.hr

For the first time, almost complete fish remains are recorded in the Sarmatian deposits of Kasonja hill (Figure 1), on the southwestern slopes of the Dilj gora Mt. According to PIKIJA et

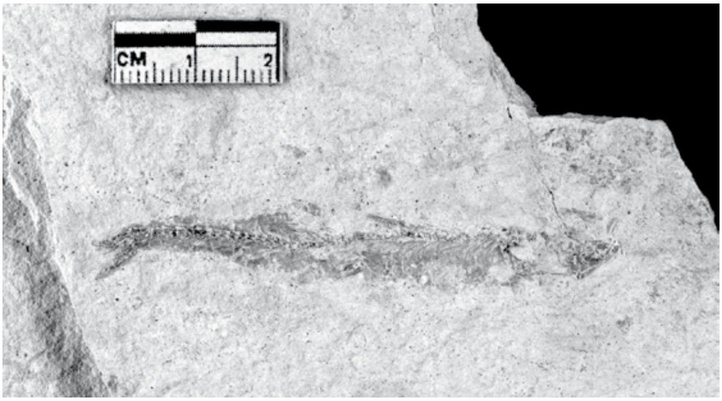

Figure 1. Fossil fish from Kasonja hill, Dilj gora Mt.

al. (2005) and KOVAČIĆ et al. (2011), eleven unformal Neogene litostrathigraphic units are described from the Dilj gora Mt. and investigated Sarmatian deposits belong to the Kasonja unit. All Sarmatian sediments from investigated area are well stratified. In the base are mostly gravels, sands and conglomerates in lesser extent, and they are overlayed by weakly cemented sandstones and marls. Along with these sandstones, biocalcarenites, oolitic calcarenits, sandy limestones, fine-grained limestone and laminated marls usually occur. In the upper layers, marls with intercalations of sandstones prevail (ŠPARICA & CRNKO, 1973). The Sarmatian sediments were deposited in a reduced marine environment (KOVAČIĆ et al., 2011).

The fossil fish is preserved as a part and counterpart in 1 cm thick layer of marly limestone. Body is elongated with total lenght of 6.5 cm. Head is partially preserved, with lenght measured of about 1/5 of total lenght. Most of the head bones are crushed, but quadratum, anguloarticular and dentare bones are quite complete. Long narrow anterior process of the second supramaxillar bone is also visible. Total count of vertebrae is 45. Dorsal fin is partially preserved near the mid-point of the body with 9 soft rays. Pectoral and pelvic fins are visible, pectorals with 14 soft rays, and pelvics with 7 soft rays. Anal fin is not preserved but the attachment at the 30th vertebrae is noticable. Caudal fin is preserved, and the rays are not countable. Body is covered with scales. According all the above mentioned characteristics, specimen is determined to belong to family Clupeidae, with a closest resemblance to the genus *Spratelloides*.

Clupeid fishes are very common in Sarmatian deposits of Northern Croatia, and are especially well known from the localities in vicinity of Zagreb (GORJANOVIĆ-KRAMBERGER, 1883).

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MICROBIALITE REEFS OF THE MIDDLE MIOCENE CARPATHIAN FOREDEEP AND LATE PERMIAN ZECHSTEIN BASINS – A COMPARISON

Marek Jasionowski[1,*], Tadeusz Peryt[1] & Paweł Raczyński[2]

[1] Polish Geological Institute – National Research Institute, 00-975 Warszawa, Poland
[2] Institute of Geological Sciences, University of Wrocław, Pl. Maksa Borna 9, 50-205 Wrocław, Poland

*corresponding author: marek.jasionowski@pgi.gov.pl

Microbialite-dominated reefs/carbonate buildups are relatively rare in Phanerozoic sedimentary record. Their presence in marine settings is usually related to stressed environmental conditions (e.g. increased or decreased salinity) and/or absence of most metazoans (e.g. after mass extinctions) as well high calcium carbonate supersaturation.

Microbialite reefs occur i.a. in the Middle Miocene (Sarmatian) Carpathian Foredeep basin (Paratethys) of the southeastern Poland (Roztocze) and western Ukraine (Medobory) as well as in the Uppermost Permian Zechstein basin of the southwestern Poland (Wolsztyn High) and the southeastern Germany (Thüringen) and generally along the edge of the Zechstein Limestone (Ca1) coastal carbonate platform from eastern Greenland trough England, Holland, Germany, Poland to Lithuania. Despite so large temporal distance (over 200 My), the reefs from both basins show some clearly visible common facies and biotic characteristics. The Lower Sarmatian (= Middle Serravallian) so called "serpulid-microbialite reefs" are composed mainly of calcite microbial precipitates; additionally, synsedimentary fibrous cements play important part in places. Reef-framework skeletal organisms are represented by serpulids and, in places, bryozoans that constitute a few percent of the rock volume only and are overgrown with the microbialites. The microbialites and the serpulid and bryozoan skeletons make together a cavernous framework usually filled up with abundant synsedimentary fibrous cements and micrite internal sediments. Reef-dwelling biota is taxonomically impoverished but often rich in individuals and comprises few species of bivalves, gastropods, foraminifers and ostracods. The Zechstein Limestone (Ca1) bryozoan-microbialite reefs are internally more complex if compare to their younger counterparts. However they are composed also, especially their uppermost portions, largely of microbialites and synsedimentary cements and the main skeletal organisms are bryozoans. In the microbialitic facies there occur taxonomically poor bivalves and gastropods, rare terebratulid brachiopods and some bryozoans.

Both the Miocene reefs and the Zechstein ones grew within marginal or isolated shallow marine carbonate platforms in restricted semi-marine (Sarmatian) or probably slightly saline (Zechstein) waters. The particular reef bodies are small (maximum tens of meters high, few hundred meters across) and can be classified as little barrier reefs, patch reefs or pinnacle reefs. The reefs from both areas are cut by fissures penetrating down for more than 10 m. The fissures' walls are coated by several generations of thick microbialitic encrustations.

EARLY TO MIDDLE MIOCENE CALCAREOUS NANNOFOSSILS FROM ALBANIAN-THESSALIAN BASIN (ALBANIA)

Mădălina-Elena Kallanxhi[1,*] & Stjepan Ćorić[2]

[1] Department of Geology, Babeș-Bolyai University, M. Kogălniceanu 1, 400084 Cluj-Napoca, Romania
[2] Geological Survey of Austria, Neulinggasse 38, A-1030 Vienna, Austria

*corresponding author: madalina_kallanxhi@yahoo.com

The Albanian-Thessalian intramontane Basin (Albania) represents the continuation of the Meso-hellenic trough (Greece), evolved as a narrow marine basin and preserves three main sedimentary sequences (PASHKO et al., 1973): the Middle Eocene sequence, the Late Rupelian to Aquitanian sequence, and the Burdigalian to Langhian sequence. The investigated transects belong to the third sedimentary sequence. The Burdigalian and Langhian sediments are restricted only to the south-eastern part of the Albanian-Thessalian Basin. They are represented by a succession composed of reddish-yellowish sandstones and conglomerates, limestones with *Lithothamnium*, thick bluish siltstones and marlstones with sandstones and conglomeratic lenses intercalations, belonging to the Morava Formation, followed by the Bradvica Formation with sandstones, bluish marlstones, sandy marls, and conglomeratic lenses intercalations, and finally the Langhian Sinica Formation represented by deep-marine bluish marlstones with fine-grained sandstones intercalations.

Quantitative and semi-quantitative investigations of calcareous nannofossils were performed on a total number of 117 samples, collected from four transects (Kodra Partizani, Mirasi-1, Mirasi-2 and Çetë). The material contains moderate to well preserved calcareous nannofossil assemblages, dominated by: *Reticulofenestra minuta* (blooms in Mirasi-1), *R. haqii*, *Coccolithus pelagicus*, *R. pseudoumbilicus, Sphenolithus heteromorphus* and *Umbilicosphaera jafari.* Other species and taxonomical groups present in less quantities, are: *Acanthoica* sp., *Braarudosphaera bigelowii*, *Calcidiscus* spp., *Coccolithus miopelagicus*, *Coronosphaera mediterranea*, *Cyclicargolithus floridanus*, *Discoaster* spp., *Hayella challengeri, Helicosphaera* spp. (*H. ampliaperta*, *H. carteri*, *H. euphratis*, *H. intermedia*, *H. mediterranea*, *H. minuta*, *H. scissura*, *H. walberdorfensis*, *H.* cf. w*altrans* and *Helicosphaera* sp.), *Holodiscolithus macroporus*, *Pontosphaera discopora*, *P. multipora*, *Pontosphaera* sp., *Reticulofenestra gelida, Reticulofenestra* sp (3 - 5µm), *Sphenolithus belemnos, S. moriformis*, *Sphenolithus* sp., *Syracosphaera pulchra*, *Triquetrorhabdulus* spp. and *Umbilicosphaera rotula.* Reworked specimens from Mesozoic and lower stages of the Paleogene are present in very low amounts.

Biostratigraphically, the calcareous nannofossil assemblages allowed the correlation of the mentioned outcrops to the following standard biozones: NN3 – *Sphenolithus belemnos* Zone of Burdigalian age, NN4 – *Helicosphaera ampliaperta* Zone (Burdigalian – Early Langhian) and NN5 – *Sphenolithus heteromorphus* Zone (of Langhian age). The biostratigraphical assignment is supported by the occurrence of several index species such as: *H. ampliaperta*, *H. walberdorfensis*, *H*. cf. *waltrans, Sphenolithus belemnos* and *S. heteromorphus.*

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INTEGRATION OF SCIENTIFIC VIEWS ON NEOGENE OF VALIS AUREA WITH THE GEOTHERMAL-ENERGY & OIL/GAS EXPLORATIONS

Slobodan Kolbah[1,*], Svjetlana Šćuric[2] & Mladen Škrlec[3]

[1] *Geological resources delineation & categorization, Geothermal Energy LLC, Ibrišimovićeva 9, 10 000 Zagreb, Croatia*

[2] *IT-expert, INA Oil Industry Plc, Lovinčićeva 4, 10 000 Zagreb, Croatia*

[3] *Geological resources production engineering, Geological resources reservoir engineering & legislation, Geothermal Energy LLC, Ibrišimovićeva 9, 10 000 Zagreb, Croatia*

*corresponding author: skolbah@gmail.com

The aim of this presentation is to emphasize the importance of interaction of scientific and utilitaristic research in geology. Here we present an overview of the deep basin relations of Neogene in Valis Aurea, useful for the scientists, and the scientific results of which can indicate new targets and decrease risk of large investments in the discovery of said targets.

The initial results of this exploration are the delineation and definition of geothermal energy resources. Long term, it is expected that in further interpretation it will be possible to delineate new objects with an increased geological reliability, due to better scientific understanding of geological data.

Our knowledge about the geothermal energy potential arises from the study of geology and characteristics of local natural geothermal springs in the frame of O&G exploration. This includes the interpretation of surface/deep geological, geophysical, geothermal and hydrodynamic deep well data, enabling spatial deep basin understanding.

– Our experiences in exploration, development and production of geothermal and mineral waters, are based on cases with long-term production, appropriate tools, techniques and

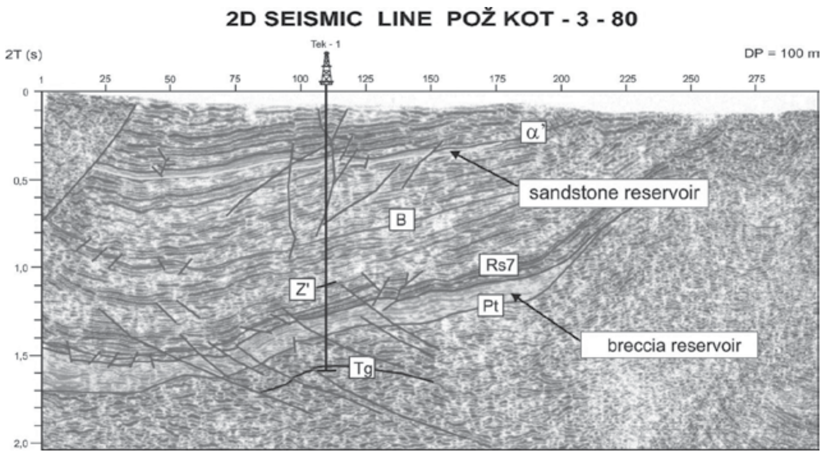

Figure 1. Interpretation of 2D seismic profiles PK-3-80 and deep well Tek-1 with the indicated geothermal water-nostril in broken Badenian carbonates below markers Rs7 and the Lake Slavonija sandstone, under the marker alpha.

technologies, supported by IT and controlled by clearly defined economic criteria, pondered by geological risks. Better understanding of geology enables us to better interpret deep geological features and significantly cut the crucial risks. Because of that, at this workshop in Valis Aurea we are particularly interested in new outlooks at local Neogene geological build up, especiallyStratigraphy and environment of geological events in the course of Early Miocene with deposits in saline and open basins, next to Poljanska

– Early (?) – Middle Miocene alluvial to lacustrine transition, Baćindol – Banićevac;

– Middle Miocene marine deposition, Našice – Bukova Glava;

– Disintegration of the Central Paratethys and origin of the Lake Pannon, Našice – Vranović;

– Badenian fossiliferous shallow marine carbonates with pyroclastics, Zdenci;

– Termination of the Lake Pannon and origin of the Lake Slavonija, Petnja.

In the existing solutions for the Valis Aurea area we distinguished two main targets: first, in broken Badenian carbonates of Vukovarska formation, below markers Rs7, and the second, in the Lake Slavonija sandstone of Vera formation, under the marker alpha (see Figure 1). As the exploration continues we are in search of new important targets.

From a scientific point of view the insight into deep basin relations is interesting and necessary for the understanding of surface detail, but also for the wider geological understanding of the area.

Cutting the geological risk and the complicated legislation are two main obstacles in development of natural resources, in particular geothermal energy, which in Croatia has not yet been recognized as an important part of the country's energy mix and it sustainable development.

HIGH-RESOLUTION ANALYSIS OF ORGANIC AND ANORGANIC PROXIES VARIATIONS IN THE SZÁK FORMATION, LAKE PANNON – PRELIMINARY RESULTS

Erika Kovács* & Radovan Pipik

Earth Science Institute, Slovak Academy of Sciences, Dumbierska 1, 97411 Banska Bystrica, Slovak Republic

*corresponding author: kovacs@savbb.sk

Lake Pannon, a large brackish Paratethyan lake from the Late Miocene (MAGYAR et al., 1999) covered the Pannonian Basin complex in the Central and Southern Europe during the Miocene and Pliocene. At the Middle Miocene-Late Miocene boundary about 12 million years ago, the water body of the basin became isolated from the sea, and Lake Pannon formed; its basin gradually filled with sediments during the subsequent 7 million years (MAGYAR et al., 1999). The lake reached its largest areal extent at ca. 9.5 million years ago, as basin subsidence continued due to cooling of the lithosphere (CZICZER et al., 2008). Between 9.0 to 8.5 Ma, a warming occurred, which is less pronounced in the Central Europe than in other parts of Europe. Factors of climate change must be sought in the internal causes due to paleogeographic changes in Central Paratethys, uplift of the mountains (KOVÁČ et al., 2011, MAGYAR et al., 1999), as well as cyclic solar activity (KERN et al., 2012).

Current research is focused on exploring the short paleoenvironmental variations in the Lake Pannon Szák Formation from the period between 9 to 8 Ma. This paper will present high-resolution preliminary results that demonstrate changes in sediment properties, total organic carbon (TOC), total carbon (TC) total inorganic carbon (TIC), $CaCO_3$, magnetic susceptibility (MS) and ostracod assemblages in the sublittoral clay succession rich in fossil meiofauna (CZICZER et al., 2008). The 6 m long clay succession has been sampled each 1 cm; MS was measured each 2 cm.

Carbon content (TC) varies from 2.71 % to 4.96 % with a higher variability in the lower part of the sequence. TOC content is low and it has a maximum content in sample 45 (1.02 %), and a minimum content in sample 449 (0.28%). Generally, TOC displays a decreasing trend toward the top of sediment sequence with a higher fluctuation in the lower part, similarly with the carbonate content. TIC and TC show identical trends. $CaCO_3$ content varies from 18.75% to 36.8%, and shows similar trend with TOC.

The average magnetic susceptibility as a function of the mineralogy, concentration and size of present magnetic minerals varies along the whole sediment column is 0.5×10^{-6} m^3kg^{-1}, but the values variations are low, ranging between 0.1×10^{-6} m^3kg^{-1} to 1.4×10^{-6} m^3kg^{-1}.

The ostracods occur along the entire investigated sedimentary column. The number of ostracods per sample varies greatly from 1 to 138 ind./50 g in sedimentary column. Fifty species are represented, dominated by endemic species and genera of candonids, leptocytherids, cypridids and loxoconchids.

Candonidae are the most abundant family on the individual and species level. Candoninae represents the most abundant taxon (29 species), it is composed of typical Paratethyan candonins – *Bakunella, Lineocypris, Serbiella, Camptocypria, Caspiocypris, Typhlocyprella* and *Zalanyiella.* The second most diverse family is the Leptocytheridae, represented by brackish *Amnicythere* and *Euxinocythere*. Cyprididae are represented by the brackish *Amplocypris* and *Herpetocyprella.* Cytherideidae represented here only by *Cyprideis macrostigma* Kollmann 1958 with well-preserved specimens. Cyclocypridinae and Loxoconchidae are rare.

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NEOGENE PALAEOGEOGRAPHY AND BASIN EVOLUTION OF THE WESTERN CARPATHIANS

Michal Kováč[1,*], Emő Márton[2], Nestor Oszczypko[3], Rastislav Vojtko[1], Silvia Králiková[1], Jozef Hók[1], Dušan Plašienka[1], Tomáš Klučiar[1], Marianna Kováčová[1], Natália Hudáčková[1], Andrej Ruman[1], Michal Šujan[1], Samuel Rybár[1] & Marta Oszczypko-Clowes[3]

[1] *Department of Geology and Palaeontology, Faculty of Natural Sciences, Comenius University in Bratislava, Mlynská dolina, Ilkovičova 6, 842 15 Bratislava, Slovakia*

[2] *Geological and Geophysical Institute of Hungary, Paleomagnetic Laboratory, Columbus u. 17–23, 1145 Budapest, Hungary*

[3] *Institute of Geological Sciences, Jagiellonian University, Oleandry 2a, 30-063 Kraków, Poland*

*corresponding author: kovacm@fns.uniba.sk

The data on the Neogene geodynamics, palaeogeography, and basin evolution of the Western Carpathians and adjoining areas (ALCAPA Mega-unit) were summarized, re-evaluated, supplemented and newly interpreted. The concept is illustrated by a series of palinspastic and palaeotopographic maps. The Miocene basins were principally assigned to two geodynamically different realms (KOVÁČ et al., 2016). The fore-axis basin system embraces various foreland depressions on the lower plate of the converging system, as well as the upper-plate fore-arc basinal area and the wedge top or piggy back basins carried by the accretionary wedge. The axial orogenic zone is represented by the exhuming and uplifting core of the Central Western Carpathians. The hinterland basins were located above mobile and wrench fault zones behind the axial zone, thus they represent the back-axis basin system. This is represented by the compressional retro-arc basin, wrench-fault furrows, or the extensional back-arc basin system in the mature stages of tectonic evolution.

The Miocene development of the Outer Western Carpathians reflects the vanishing subduction of the residual oceanic and/or thinned continental crust. A compression perpendicular to the front of the orogenic system led to closing of residual flysch troughs and to accretionary wedge growth; as well as to the development of basins on the slope and shelf of the European Platform passive margin – the peripheral foredeep.

Docking of the Outer Western Carpathians accretionary wedge, together with the Central Western Carpathians, was accompanied by stretching of the overriding microplate. An extension parallel and perpendicular to the orogen was associated with the opening and subsidence of the Early and Middle Miocene hinterland (back-arc) basin system that compensated counter-clockwise rotations of the individual crustal fragments of ALCAPA. The Late Miocene development relates to the opening of the Pannonian Basin System. This process was coupled with common stretching of both ALCAPA and Tisza-Dacia Mega-units due to the pull exerted by subduction rollback in front of the Eastern Carpathians. The filling up of the hinterland basin system was associated with the thermal subsidence and was followed by the Pliocene tectonic inversion and consequent erosion of the basin system margins.

The Oligocene–Early Miocene exhumation and uplift of the axial orogenic zone of the Central Western Carpathians led to the removal of the Palaeogene and Mesozoic sequences from the crystalline basements in the west (Danube Basin pre-Neogene basement). The central and eastern parts of the internal Central Western Carpathians zones were gradually exhumed and some of them appeared at the erosional surface in this time as well. Exhumation of the external Central Western Carpathians zones along the Pieniny Klippen Belt was caused by the collision of the Western Carpathian orogenic wedge with the European continental margin during the Middle Miocene. This process was accompanied by denudation of the Palaeogene and Lower Miocene deposits in the north, providing a source of clastic material for the hinterland basin system in the south during the Middle and Late Miocene.

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FACIES ANALYSIS, MINERAL ASSEMBLAGE AND PROVENANCE OF PLIOCENE SEDIMENTS FROM THE AREA OF VUKOMERIČKE GORICE (CENTRAL CROATIA)

Tomislav Kurečić[1,*], Marijan Kovačić[2] & Anita Grizelj[1]

[1] *Croatian Geological Survey, Sachsova 2, HR-10000 Zagreb, Croatia*

[2] *University of Zagreb, Faculty of Science, Department of Geology, Horvatovac 95, HR-10000 Zagreb, Croatia*

*corresponding author: tomislav.kurecic@hgi-cgs.hr

The subject of research were Pliocene sediments from the area of Vukomeričke Gorice (Central Croatia). These sediments are commonly called *Viviparus* beds after the evolutionary lineage of the gastropod genus *Viviparus*. *Viviparus* beds were deposited in the Lake Slavonia, ancient lake that existed in the S and SW part of the Pannonian Basin System (PBS) during Cernikian (MANDIC et al., 2015).

The aim of this research was to determine the depositional environments and provenance of *Viviparus* beds. For this purpose, detailed field investigations, as well as mineralogical, petrographic, chemical and paleontological analyses were performed in the area of Vukomeričke Gorice. These sediments were correlated with similar coeval deposits from the SW slopes of Psunj Mt. and S slopes of Dilj Mt. in Slavonia (Eastern Croatia).

Facies analysis and fossil assemblage point that *Viviparus* beds were deposited during Lower and Upper Cernikian in freshwater lacustrine and alluvial environments. Lacustrine sediments are represented by fossiliferous clayey silts which were deposited in the littoral part of the freshwater lake, and by sandy sediments deposited at the river mouth. Alluvial deposits consist of river channel sandy-gravelly sediments and heterolithic pelitic-sandy overbank sediments. The vertical intertwining of lacustrine and alluvial sediments indicates occasional water level fluctuations in the lake, and suggests that the studied area was situated in a marginal part of the lake. Vertical facies relations suggest also a general coarsening upwards trend from the Lower *Viviparus* beds towards the end of the Pliocene, i.e. Upper *Viviparus* beds. Parts of the area of Vukomeričke Gorice, which were not covered by lake, formed terrestrial environments with a well-developed braided river network.

The structural immaturity of the sandy-gravelly detritus points to a relatively short transport of the material of the *Viviparus* beds. According to the paleotransport directions and modal composition, source of detritus were different magmatic, metamorphic end older sedimentary rocks from surrounding, partially uplifted areas of Banovina, Žumberak, Medvednica and Moslavačka Gora Mts. Significant amount of detritus was redeposited also from the Upper Miocene bedrock sediments of the Alpine origin. Most of the detritus of investigated Pliocene deposits from Slavonija have Alpine provenance as well, but the presence of pyroxenes in these detritus indicates sporadic material input from the Inner Dinarides. The quite uniform modal and chemical compositions throughout the vertical distribution of the sediments clearly imply that the provenance of the material did not change during the deposition of the *Viviparus* beds.

The stratigraphically upper limit of the *Viviparus* beds is not clearly distinguished in the investigated area. Appearance of Pleistocene slope deposits and braided river deposits, as well as the covering loess, testify to the end of Pliocene lacustrine sedimentary conditions. Nevertheless, it is clearly related to the basin inversion due to the compression of PBS during the Pleistocene, which resulted with the uplift of the surrounding mountains (PAVELIĆ, 2001). Subsequently, Vukomeričke gorice were uplifted and the sediment accommodation area was reduced on the western margins of the Lake Slavonia.

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TAXONOMY AND PALEOECOLOGY OF *BUDMANIA* BRUSINA, A SUBGENUS OF *LYMNOCARDIUM*, FROM THE UPPER MIOCENE OF THE PANNONIAN BASIN

Imre Magyar[1, 2 *], Lajos Katona[3], Krisztina Sebe[4] & Ádám Kovács[4]

[1] *MTA–MTM–ELTE Research Group for Paleontology, Budapest, Hungary*

[2] *MOL Hungarian Oil and Gas Plc., Budapest, Hungary*

[3] *Natural History Museum of the Bakony Mountains, Zirc, Hungary*

[4] *Department of Geology and Meteorology, University of Pécs, Hungary*

*corresponding author: immagyar@mol.hu

Long-lived lakes are often sites of endemic evolution in various groups of their biota. Well-known examples include molluscs, which sometimes develop spectacular morphologies in such lakes. The most puzzling „freaks" from the Late Miocene – Pliocene Lake Pannon in Central Europe include *Budmania* Brusina 1897, a subgenus of the brackish-water cockle *Lymnocardium*. These bivalves bear spectaculary high radial ribs with a keel, which, unlike in any other cardiid, sometimes have a T-shaped profile, and the distal parts of such neighbouring keels may be welded in some individuals.

These fossils occur in many localities in the southern part of the Pannonian basin, but their best-known locality is Tirol (Romanian)/Királykegye (Hungarian)/Königsgnad (German) in the Banat region. This outcrop, discovered by Gyula Halaváts at the end of the 19th century, yielded well-preserved specimens of *Budmania* in apparently unlimited quantity. These shells became treasured items of many fossil collections worldwide. Several attempts were made to explain the unusual shell morphology of this cockle, but even the most thoroughful, 21st century study (SAVAZZI & SÄLGEBACK, 2004) came to the same conclusion as the previous ones, namely that the sail-like radial ribs probably facilitated anchoring in the soft sediment.

In the 100 years between 1874 and 1973, 8 species names were introduced for various morphotypes of this group, although most authors believed that part of these names were synonyms, and there are only a few distinguishable species. We identified the original type materials, analysed the species descriptions and differential diagnoses, and checked what materials were available for the describers of new species. It turned out that only two basic morphologies, i.e. two species can be distinguished within the subgenus. The first one is *Lymnocardium ferruginuem* (Brusina), the original specimens of which were preserved in iron-stained sandstone as moulds and prints. The second one is *Lymnocardium cristagalli* (Roth), the type specimens of which are well-preserved shelly individuals from multiple localities.

Although the characteristic rib morphology is a shared character, the two species do differ in other morphological traits. In general, *L. ferrugineum* shows close similarity to *L. inflatum* (Gorjanović-Kramberger), whereas *L. cristagalli* to *L. hungaricum* (M. Hörnes). As a consequence, the phylogenetic relationship between *L. ferrugineum* and *L. cristagalli*, i.e. the monophyly of the subgenus *Budmania*, is questionable.

Our investigations showed that the two species preferred different habitats. The valves of *L. ferrugineum* are usually found in coarse-grained sand, together with those of littoral, shallow-water, sometimes even freshwater-tolerant molluscs, such as *Prosodacnomya, Dreissenomya, Congeria triangularis, Viviparus*. *L. cristagalli*, however, is found in fine-grined sediments (silt, clay, marl), and it is accompanied by sublittoral forms, such as *Lymnocardium majeri, L. hungaricum, Congeria rhomboidea, C. zagrabiensis*, and deepwater-dwelling pulmonate snails.

The different habitats and the possibly independent phylogeny of the two species suggest that the highly unusal rib morphology was not a result of a unique adaptation strategy. Reasons for development of this conspicuous feature remain veiled and their understanding requires further study and testing of new hypotheses.

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CORRELATION OF MIOCENE VOLCANICS BY THE COMBINATION OF PALEOMAGNETIC MARKER HORIZONS AND MAGNETIC POLARITIES: NEW RESULTS FROM THE BÜKK AND MÁTRA MTS, NORTHERN HUNGARY

Emő Márton[1,*], Dávid Karátson[2], Tamás Biró[2] & Mátyás Hencz[2]

[1] *Geological and Geophysical Institute of Hungary, Palaeomagnetic Laboratory, Columbus 17-23, H1145 Budapest, Hungary*

[2] *Eötvös University, Institute of Geography and Earth Sciences, Department of Physical Geography, Pázmány Péter Sétány 1/C, H1117, Budapest, Hungary*

*corresponding author: paleo@mfgi.hu, mar11000@mail.iif.hu

The first paleomagnetic investigations in the Neogene volcanic areas of the Pannonian basin (e.g. MÁRTON & MÁRTON, 1968, 1969, DAGLEY & ADE-HALL, 1970, NAIRN et al., 1971, ANDÓ et al., 1977, BALLA & MÁRTON, 1978) were aiming at dating and correlating volcanic rocks by magnetic polarities. Later, two CCW rotation events of Miocene age were recognized in the area of the North Hungarian Paleogene basin (MÁRTON & MÁRTON, 1996), providing significant marker horizons (a one-way pattern of declination change) which combined with traditional magnetostratigraphy could make age estimation and correlation highly reliable. Moreover, the rotational events were related to the two older "tuff complexes" of the Pannonian basin, while the third one was emplaced after the rotations.

The application of the combination of paleomagnetic marker horizons and polarity lead to the revision of the stratigraphic classification of some key localities, subsequently supported by isotope ages.

Recently, interest renewed in the "tuff complexes" of Northern Hungary. One of the aims of the new investigations is to refine the subdivision and correlation of different horizons with lithological, geochemical and paleomagnetic methods, another is to obtain isotope ages from zircons (ref), which are thought more reliable than the K/Ar ages (MÁRTON & PÉCSKAY, 1998).

In this presentation we focus on the results of the recent paleomagnetic investigations. Improved technical conditions made possible to drill paleomagnetic samples in the field in quite loose members of the "tuff complexes" sometimes from the matrix, sometimes also from small-size pumices from the same site, and even only from pumices, when the matrix was too loose. This way, we were able to obtain results not only from geographically distributed sites, as before, but also from several horizons from the same section, where the age relations between the horizons are evident in the field. The results of the recent investigations in combination with relevant earlier obtained paleomagnetic results will be discussed from the viewpoint of the power of the method in precise stratigraphic correlation.

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TENTATIVE CORRELATION TO THE STANDARD POLARITY TIME SCALE OF A 100m LONG DRILL CORE FROM THE TURIEC BASIN, SLOVAKIA

Emő Márton[1,*], Radovan Pipík[2], Dušan Starek[2] & Erika Kovács[3]

[1] Geological and Geophysical Institute of Hungary, Palaeomagnetic Laboratory, Columbus 17-23, 1143 Budapest, Hungary

[2] Earth Science Institute of Slovak Academy of Sciences, Ďumbierska 1, 974 01 Banská Bystrica, Slovak Republic

[3] Earth Science Institute of Slovak Academy of Sciences, Dúbravská cesta 9, 840 05 Bratislava, Slovak Republic

*corresponding author: paleo@mfgi.hu, mar11000@mail.iif.hu

The origin of the basin is linked with transtensional/extensional regime in the Middle Miocene (KOVÁČ et al., 2011, PIPÍK et al., 2012). In the late Miocene it was isolated a freshwater lake, where pelitic sedimentation took place. In the Latest Miocene/Pliocene it was uplifted and fluvial gravel deposited. The aim of drilling in the South part of the basin was the study of climatic change and paleoenvironmental evolution during the Late Miocene. As dating and correlation with the international stratigraphic scale was difficult, due to the endemic deep and freshwater fauna, the fresh core material was studied for magnetostratigraphy.

Magnetic mineralogy experiments carried out on several core segments as well as the stepwise thermal demagnetization accompanied by susceptibility monitoring indicated that the magnetic signal was connected to greigite. As greigite is always of diagnetic origin in sediments, indicating suboxic/anoxic conditions close to the water/sediment interface, it is essential to document the consistency of the paleomagnetic directions throughout the core, thus making the early diagenetic origin of the magnetic mineral plausible. As the core segments were not oriented azimuthally, we reoriented them with respect to each other using thin silt intercalations as well as the magnetic fabrics. Finally, the paleomagnetic directions thus obtained were re-oriented so that the dip of the intercalated silt and that of the AMS foliation correspond to the general tilt measured at the drilling site. This overall-mean paleomagnetic direction defined for the drill core perfectly fits the tilt corrected paleomagnetic directions obtained for a number of Late Miocene outcrops from the Turiec basin (MÁRTON et al., 2016), further supporting the early diagenetic age of the magnetic signals of the drill core.

The majority of the studied samples exhibit normal polarity. Reversed polarity samples appear in three levels, but neither their numbers nor their quality justifies to define these levels as reversed polarity events. We tentatively correlate the drill core to a relatively long normal polarity zone around 8 Ma, with a duration of about 1Ma.

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PROGRESS IN THE PROVENANCE STUDY OF PLIO-QUAERNARY SEDIMENTS IN SLOVENIA

Eva Mencin Gale[1, 2, *], Petra Jamšek Rupnik[1], Miloš Bavec[1], Flavio S. Anselmetti[2] & Andrej Šmuc[3]

[1] *Geological Survey of Slovenia, Dimičeva 14, 1000 Ljubljana, Slovenia**

[2] *University of Bern, Institute of Geological Sciences and Oeschger Centre for Climate Change Research, Baltzerstrasse 1+3, 3012 Bern, Switzerland*

[3] *University of Ljubljana, Faculty of Natural Sciences and Engineering, Department for Geology, Aškerčeva 12, 1000 Ljubljana, Slovenia*

*corresponding author: eva.mencin-gale@geo-zs.si

Slovenia lies at the junction of three large entities: the Alps, the Dinarides and the Pannonian Basin (PLACER, 2008). The landscape evolution was strongly influenced by the formation of the Alps and Dinarides resulting in a hilly and mountainous terrain with depressions providing space for various sedimentary archives. The onset of youngest terrestrial sedimentation in this area is represented by the deposits informally called the “Plio-Quaternary”. It comprises a succession of alluvial clastic sediments and is preserved in topographic depressions, as well as on higher

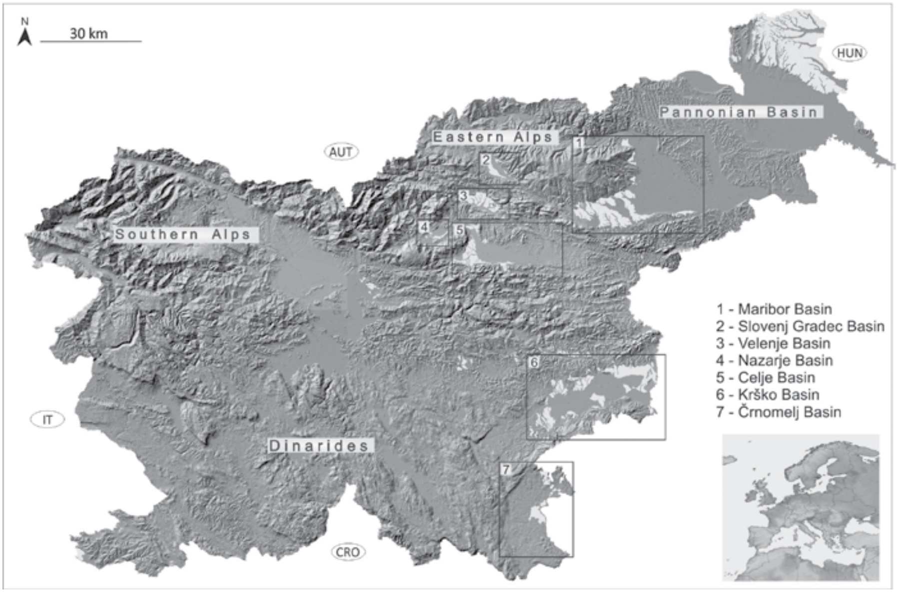

Figure 1. Spatial distribution of intramountain basins and Plio-Quaternary sediments in Slovenia. Geotectonic units are modified after PLACER (2008).

areas indicating base-level lowering and post-depositional deformation (e.g.: VRABEC, 1999; VERBIČ, 2005). Plio-Quaternary sediments in Slovenia are preserved in several intramountain basins: Maribor, Slovenj Gradec, Velenje, Nazarje, Celje, Črnomelj and Krško basins (Figure 1). State-of-the-art studies targeting their composition, provenance, genesis and age have been, with few exemptions (e.g. Krško basin), nonsystematic and yielded ambiguous results. This study therefore aims to enhance the understanding of the Plio-Quaternary sedimentation and the environmental evolution of the proposed intramountain basins.

The ongoing research is focused on stratigraphic correlation and provenance and is based on multi-methodological approach: clast lithological analysis, analysis of roundness and shape of the pebbles and weathering surfaces, heavy and light minerals analysis, X-ray diffraction, X-ray fluorescence analysis, analysis of changes in the elemental composition with depth to quantify post-depositional weathering (EVANS & BENN, 2004) and carbonate content analysis of the matrix to address the enigmatic lack of carbonate pebbles in most of the Plio-Quaternary deposits. Preliminary results based on fieldwork indicate that Plio-Quaternary sediments were deposited in fluvial and lacustrine systems. The comparison of the composition of the sediments reveals two major source areas. For sediments deposited in Slovenj Gradec, Velenje, Nazarje, Maribor and Celje basins the source area are the Eastern Alps, whereas the deposits in Krško and Črnomelj basin derive from the Southern Alps. First results from organic and inorganic carbon analysis, which in this case can be used as an additional provenance deciphering tool, were obtained. Analyses were focused on the ten matrix samples (< 2 mm and <0.063 mm fraction from each sample) from Maribor, Slovenj Gradec and Nazarje basins. No significantly high values of $CaCO_3$ were measured in the samples from Maribor and Slovenj Gradec basins, supporting the

Eastern Alps provenance where predominantly crystalline rocks occur. However in one sample (out of four) from Nazarje basin 12.5 % and 25.1% concentration of $CaCO_3$ were measured in the fractions < 0.063 mm and < 2 mm, respectively, which could indicate local carbonate origin.

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THALASSIPHORA BALCANICA: MORPHOLOGY AND PALEOECOLOGY OF A PONTIAN-STAGE DINOFLAGELLATE CYST

Peta J. Mudie[1,*], Andre Rochon[2], Koraljka Bakrač[3] & Robert A. Fensome[1]

[1] *Natural Resources Canada, Geological Survey of Canada (Atlantic), Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, Nova Scotia, B2Y 4A2 Canada*

[2] *Institut des sciences de la mer de Rimouski, ISMER, 310 allée des Ursulines, Rimouski QC, G5L 3A1, Canada*

[3] *Croatian Geological Survey, Department of Geology, Sachsova 2, HR-10000, Zagreb, Croatia*

*corresponding author: mudiep@ns.sympatico.ca

Our study aims to clarify the identity of some late Neogene dinoflagellate cyst taxa commonly used to establish a chronostratigraphy for non-marine sediments in the Pannonian Basin of the western Paratethys. BALTEŞ (1971) found an abundance of dinoflagellate cysts (dinocysts) in the brackish water Lower Pliocene deposits of Romania that seemed to a reflect connection with the Dacian and Euxinian (Black Sea) Basins. He described a distinctive species *Thalassiphora balcanica* with a fibrous "lamellate wing", indicating that it was abundant in the Lower Pliocene (Pontian) interval of the Pannonian Depression and Moesique Platform of the Carpathian Foreland. Balteş and others noted the similarity of this Pontian species to some Paleogene *Thalassiphora* species, particularly *Thalassiphora pelagica*. However, based on new Upper Pannonian specimens from the Paks borehole in Hungary, SÜTŐ-SZENTAI (2000) transferred *Thalassiphora balcanica* to *Spiniferites,* believing that the cyst had branched processes characteristic of the latter genus. She considered five types of "winged" dinocysts in the "*Galeacysta estrusca* complex" of POPESCU et al. (2009) to be ecomorphotypes adapted to salinity gradients, and used them to subdivide the Pannonian interval (SÜTŐNÉ-SZENTAI, 2011). Three "winged" members of this "G. etrusca complex" were also used for a Late Pannonian biozonation of the Dacic Basin in Croatia (BAKRAČ et al., 2012). Our new research uses transmitted and fluorescent light microscopy and scanning electron microscopy to study Croatian samples from Pontian-stage brackish-lacustrine sediments and to compare the morphology of *Spiniferites balcanicus* with *Thalassiphora pelagica, Galeacysta estrusca, Spiniferites cruciformis*, and *Pterocysta cruciformis*. We find that the fibrous, finely subreticulate periphragmal "wing" of *Spiniferites balcanicus* is very similar to that of the bowl-shaped, fibro-reticulate periphragm of *T. pelagica* and its allies, and that there is no evidence of the branched processes that distinguish *Spiniferites*. The extent of periphragm development is variable within a single sediment sample, raising questions about its correlation with salinity. The periphragm of *Thalassiphora balcanica* has a large ventral opening as in *Galeacysta etrusca,* but the latter is easily distinguished by its galeate apical "wing" attachment and its large claustrate periphragm openings. One variant of *Thalassiphora balcanica* superficially resembles *Pterocysta cruciformis* in having a subcruciform body and large periphragm perforations. However, the apical periphragm attachment is different and the "wing" does not cover the mid-ventral surface. All morphotypes of *Thalassiphora balcanica* differ from *Spiniferites cruciformis* in not having branched processes with connecting membranous flanges. In conclusion, our new data confirm that a more reliable zonation of the Central Paratethyan Pannonian Stage is obtained if *Thalassiphora balcanica*, *Galeacysta. etrusca* and *Spiniferites cruciformis* are recognised as separate species displaying successive first occurrences from late Early Pannonian (NN9b) to latest Late Pannonian (NN11) respectively. Ongoing research on Pleistocene–Holocene sediments in the Caspian Sea suggests these taxa persisted in low salinity (2 to 15 psu) environments of this endorheic basin (e.g. RICHARDS et al., 2017).

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ENVIRONMENTAL CHANGES AT THE BADENIAN/SARMATIAN (MIDDLE MIOCENE) TRANSITION IN CENTRAL PARATETHYS (KREMINNA, W UKRAINE): FORAMINIFERAL EVIDENCE

Danuta Peryt[1,*] & Marek Jasionowski[2]

[1] Institute of Paleobiology, Polish Academy of Sciences, 00-818 Warszawa, Poland
[2] Polish Geological Institute – National Research Institute, 00-975 Warszawa, Poland

*corresponding author: d.peryt@twarda.pan.pl

The Badenian/Sarmatian boundary in the Central Paratethys, that marks the transition from normal marine to restricted semi-marine conditions due to isolation of the basin from the world ocean at the onset of Sarmatian time, is still far away from full understanding. The Kreminna section is located at the northeastern margin of the Carpathian foreland basin (Central Paratethys) in the Medobory Hills region, ~60 km north to the town of Kamyanets Podil's'kyi and 50 km northeast to the town of Khmeln'nyts'kyi (Ukraine, Khmeln'nyts'kyi province). The Miocene deposits that overlie here the Upper Cretaceous substratum comprise the 2 m thick upper Badenian clays and marly clays passing upwards into 5 m-thick Sarmatian marls and clays with limestone intercalations and 2 m-thick limestones in the uppermost part.

28 species of benthic foraminifera have been recorded. Benthic foraminiferal assemblages are composed almost exclusively of calcareous forms; agglutinated ones are practically lacking. *Elphidium* spp., hauerinids, *Lobatula lobatula* and *Ammonia* spp. are the most common calcareous benthic foraminifera in the studied material. Planktonic ones represented only by the *Globigerina* species which indicate cool-water, occur rarely in the lowermost part of the section.

The analysis of foraminiferal assemblages of the section suggests cold water, inner shelf depths with short-term fluctuations in depth and salinity. A foraminiferal assemblage from clays and marly clays of the basal part of the section yielded benthic Badenian and a few reworked Cretaceous foraminifers with traces of abrasion; this assemblage suggests a high energy coastal environment. The second assemblage from a lowest limestone bed is a monospecific assemblage with *Lobatula lobatula.* This assemblage indicates shallow shelf high energy environment. The next assemblage with common *Elphidium*, *Lobatula lobatula,* hauerinids and *Ammonia* from marls is interpreted as reflecting a shallowing of the sea and a decrease in salinity. The next assemblage from marly clays is almost entirely composed of *Ammonia* spp. what suggests a brackish shallow shelf environment. The succeeding assemblage from a limestone bed which is almost entirely composed of Hauerinidae suggests an increase in salinity. Higher up in the section, the foraminiferal assemblage from marls and clayey beds is characterized by common *Ammonia* and *Elphidium*; it suggests a brackish shallow shelf environment. Foraminiferal assemblage with *Elphidium* and hauerinids from the lower part of uppermost limestone bed indicates an increase in salinity while *Ammonia* and *Elphidium* assemblage from the topmost part of the limestone indicates again a decrease in salinity.

MIDDLE MIOCENE BADENIAN – SARMATIAN SEDIMENTARY SEQUENCE IN THE AREA OF DONJE OREŠJE (MEDVEDNICA MT., CROATIA)

Đurđica Pezelj*, Jasenka Sremac, Marijan Kovačić, Sanel Alagić & Štefica Kampić

University of Zagreb, Faculty of Science, Department of Geology, HR-10000 Zagreb, Croatia

*corresponding author: djurdjica.pezelj@geol.pmf.hr

In a quarry of Donje Orešje in eastern part of the Medvednica Mt., a sedimentary succession is exposed, with Cretaceous deposits in the base, and transgressively deposited Middle Miocene sequence in the upper part (ŠIMUNIĆ et al., 1982, KOROLIJA et al., 1995). Research area was, during the Miocene, a part of the Pannonian Basin System within the Central Paratethys. Cretaceous deposits are represented with pelagic biomicrites. Planktonic foraminifera *Globotruncanita elevata* Brotzen is indicative for the Early Campanian. Temporary input of reef debris indicates several storm episodes (SREMAC et al., 2005). Date shell (*Lithophaga*) borings in Cretaceous limestone and sporadic occurrence of coastal conglomerates mark the transgressive Cretaceous/Miocene boundary.

Middle Miocene deposits consist of seven meters thick succession of thin bedded horizontally laminated calcite rich marls and fossiliferous mudstones with rare intercalations of algal grainstone. Sedimentary features exhibit only minor oscillations, with domination of carbonate component (between 50 to 90%). Horizontal lamination is more common in the upper part of the sequence. Preliminary research of microfauna has shown a continuous transition from the Late Badenian to the Early Sarmatian within the lithologically rather uniform sequence.

Basal Miocene horizon belongs to the *Bulimina-Bolivina* Zone and exhibits general deepening of the sedimentary basin from the inner-middle shelf (*Asterigerinata–Cibicidoides–Cassidulina* assemblages) to the outer shelf (*Bolivina–Cassidulina* assemblage). Percentage of planktonic foraminifera varies from layer to layer (2-85%), indicating the oscillations of the sea level during the Late Badenian.

Early Sarmatian *Anomalinoides dividens* Zone is marked by low-diversity benthic foraminiferal assemblage, with domination of species *Anomalinoides dividens* (ŁUCZKOWSKA) and index ostracod species *Cytheridea hungarica* (ZALÁNY). Significant amount of species *Bolivina dilatata* REUSS, *Cibicidoides pseudoungerianus* (D'ORBIGNY) and *Cassidulina laevigata* D'ORBIGNY point to the transitional (Badenian/Sarmatian) character of this horizon, still with normal salinity.

Further shallowing-upward process results with faunal change associated with *Elphidium reginum* Zone. Diverse species of the genus *Elphidium*, together with *Ammonia vienensis* (D'ORBIGNY) and still abundant *A. badenensis* occur within this horizon. Significant amount of brackish taxa points to the possible sea-level drop and input of fresh-water into the basin. Brackish ostracods, present in amount of up to 15%, mostly exhibit robust, highly calcified carpaces, indicating the shallower and more agitated environment, than in *Anomalinoides dividens* Zone.

Uppermost part of the sequence comprises the microfauna typical for the Sarmatian *Elphidium hauerinum* Zone, with predominance of the zone fossil *E. hauerinum* (D'ORBIGNY), associated with *E. josephinum* (D'ORBIGNY) and *E. obtusum* (D'ORBIGNY). Within this assemblage a slight, but important increase of disoxic and infaunal taxa can be observed, indicating the slight deepening of the basin and/or increase of the organic matter content within the sediment.

Microfossils are crucial for positioning of the Badenian/Sarmatian boundary. Sarmatian microfossil assemblages point to the decrease of palaeoecological proxies (P/B ratio, number of species, diversity indices) and raise of oxygen level at the sea-bottom (higher values of BFOI) in comparison with Badenian assemblages. Lower percentage of planktonic taxa (1–16%), together with other proxies, point to the inner shelf environment during the Sarmatian in the research area.

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PONTIAN REGIOSTAGE OF THE EASTERN PARATETHYS AND CONNECTIONS WITH MEDITERRANEAN AT LATE MIOCENE

Sergey Popov[1,*], Eleonora Radionova[2] & Larisa Golovina[2]

[1] Borissiak Paleontological Institute RAS, Profsoyuznaya ul. 123, Moscow, 117997, Russia
[2] Russia Geological Institute RAS, Pyzhevskiy per. 7, Moscow, 119017, Russia

*corresponding author: serg.pop@mail.ru

The Pontian as regional stratigraphic subdivision was proposed by BARBOT DE MARNY (1869, see PONTIEN, 1989). Stratotype and lectostratotype of the Pontian are situated in Odessa Town and include lower Pontian (Novorossian Substage) only. Neostratotype is Kamishburun Profile southward from Kerch Town, where ANDRUSOV (1889, 1917) subdivided Pontian to Lower – Novorossian, and Upper – Bosphorian substages with *Congeria subrhomboidea* beds between its. Later these beds often were called as the Portaferian beds. But originally this term was proposed by STEVANOVIĆ (1951, see PONTIEN, 1989) for the Pannonian Basin of Serbia, which isn't correlatable with the Eastern Paratethys Pontian successions. What is why we prefer to use Andrusov' term.

Lower boundary of the Pontian is marked by appearance of specific brackish Paratethys endemics among mollusks, ostracods, dinocysts (*Caspidinium rugosum, Galeocysta etrusca*). Nevertheless, oceanic diatom flora and nannoplankton, appeared here at the Late Maeotian, continue to meet. This boundary was dated 6.1 Ma by paleomagnetic data (TRUBIKHIN, see PONTIEN, 1989; VASILIEV et al., 2011) and by diatoms and nannofossils records (RADIONOVA & GOLOVINA, 2012). In accordance with our data there is a close correlation of Maeotian/Pontian boundary in DSDP Hole 380A and in the Zhelezniy Rog Section: in both sections established

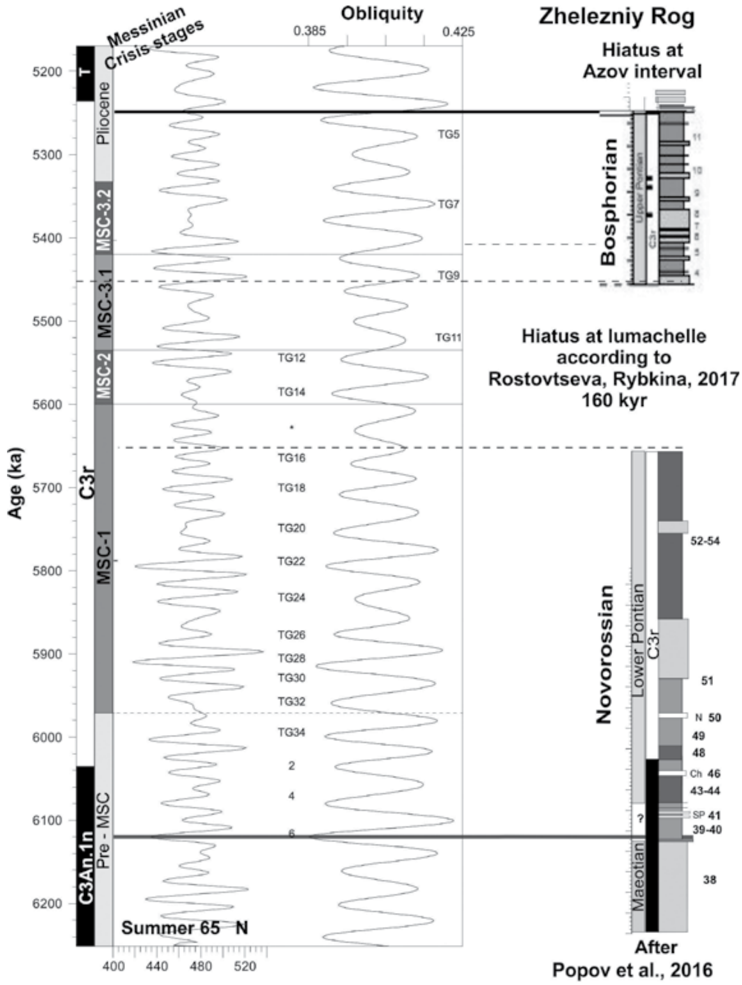

Figure 1. The cyclostratigraphic and paleomagnetic correlation of Pontian Regiostage with Messinian Salinity Crisis stages (our interpretation of the key-section Zhelezniy Rog, Taman Peninsula, after van BAAK et al., in press).

the same sequence of appearance of reference diatom species and intervals with nannoplankton and marine diatom flora (RADIONOVA & GOLOVINA, 2012). At the beginning of Pontian the connection with Mediterranean was permanent, but very soon became discontinuous and assumed the character of the distinct pulses. The final disconnection with the Mediterranean dates at 5.9 Ma, when the basin became brackish with lacustrine diatom flora and dinocyst (GROTHE et al., 2014; van BAAK et al., 2017).

Novorossian duration is estimated as 400 kyr in Zhelezniy Rog key section (Taman Peninsula) (Figure 1) on base of astronomical cyclicity, according to ROSTOVTSEVA & RYBKINA (2017). Unconformity and lumachelle (*Congeria subrhomboidea* beds) between Novorossian/Bosphorian substages correspond to peak of the Messinian Crisis. According ROSTOVTSEVA & RYBKINA (2017), hiatus at this boundary is continued 160 kyr (within 5.65-5.45 Ma).

Erosion contact between Bosphorian and Kamishburun beds of Kimmerian is the most usual. Rare full successions show continues transition to Azov beds (VASSOEVICH & EBERSIN, 1930, see PONTIEN, 1989) in vicinity of the Thvera event in paleomagnetic scale (5.2 Ma).

The Thracean-Aegean region was an area with mainly continental deposition during long time from the late Oligocene to middle Miocene. Sedimentological evidences from the roughly terrigenous sediments testify intensive uplift environments in the South Balkans. Marine connections with the Mediterranean took place via the Pre-Alpine and Slovenian corridors and in Transcaucasian during this time (RÖGL, 1998; POPOV et al., 2004).

Marine environments were restorated at the early Messinian and then changed to brackish ones with the Pontian-like mollusk and ostracod fauna (POPOV & NEVESSKAYA, 2000). According to SNEL et al. (2006) these deposits of the Choumnikon Formation are characterised by normal polarity and correspond to C3An.1n Subchron (6.30-6.04 Ma). We believe that the origin of the Choumnikon brackish fauna is related to the Pannonian biota. At the beginning Pontian this fauna populated the Eastern Paratethys. The species of the Late Pontian fauna inhabited the Mediterranean at the "Lago-Mare" stage (ESU, 2007) at 5.42 Ma.

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CONTROVERSIES ON KARPATIAN AND BADENIAN TRANSGRESSIONS IN CROATIAN PART OF THE PANNONIAN BASIN SYSTEM (BIOSTRATIGRAPHY AND PALEOENVIRONMENTS)

Vlasta Premec Fuček[1,*], Morana Hernitz Kučenjak[1], Krešimir Krizmanić[1], Jasna Tadej[2] & Slađana Zlatar[1]

[1] *INA – industrija nafte d.d., Exploration sector; Lovinčićeva 4, 10002 Zagreb, Croatia*
[2] *INA – industrija nafte d.d., Exploration sector, V. Holjevca 10, 10000 Zagreb, Croatia*

*corresponding author: vlasta.premec-fucek@ina.hr

The opening of the Pannonian Basin System during the Early Miocene is a result of the intense extension tectonics between the Alps, Carpathians and Dinarides orogens. Miocene sediments in northern and central Croatia were deposited in several basins which belong to the southwest part of the Central Paratethys. One of the most important in hydrocarbon exploration is Sava Depression, oriented from NW to SE, and characterized by a great thickness of the Tertiary sediments with over than 5000 metres.

The detailed biostratigraphic study was based on rock material from drill-cuttings and cored intervals from deep exploration wells in the Sava Depression in order to determine the age and paleoenvironment of the marine sediments. On the basis of biostratigraphic, petrographic and well logs data five marine transgressions were defined from the Late Karpatian to Sarmatian and compared with global 3rd order sequences after HARDENBOL et al., 1998 and HOHENEGGER et al., 2014. Continuous marine sedimentation during this period was confirmed in the deepest part of depression.

The oldest Miocene sediments discontinuously overlie Palaeozoic and Mesozoic basement rocks. These sediments, which consist of breccias, conglomerates, sandstones and marls originate in fluvial to lacustrine environments. As these fresh water sediments usually do not contain any microfossils, Ottnangian to Lower Karpatian age is assumed.

First marine transgression (corresponds to the TB 2.2, 3rd order sequence) is recorded in wells situated in the deepest parts of the Sava Depression. Sediments consist of dark marls and silty marls with planktonic foraminiferal assemblage that implies Late Karpatian zone *Globigerinoides trilobus.* At the same time, in the shallow shelf area, small benthic foraminifera dominate.

Lowest occurrence (LO) of the planktonic species *Globigerinoides sicanus* marked Karpatian/Badenian boundary (IACCARINO et al., 2011). Lower Badenian (TB 2.3, 3rd order sequence) mainly presented by fossiliferous marls and calcareous marls, contain very rich and highly diverse planktonic foraminiferal assemblages which indicate open sea environment, warm to subtropical climate, well stratified water column and excellent connection with Mediterranean bioprovinces.

LO of *Praeorbulina circularis* marked Early/Middle Badenian boundary and approximately corresponds to the beginning of TB 2.4, 3rd order sequence. Planktonic foraminiferal assemblages of the Middle Badenian are dominated by *Praeorbulina* and *Orbulina* species.

Although significant decrease of the sea level occurs in the Late Badenian, smaller scale transgressive cycle was recorded (TB 2.5, 3rd order sequence). Deep water marine niche were replaced by reef and perireef environments. Corallinacean-bryozoans associations produce huge amount of reef carbonates, which were mostly destructed and redeposited. However, in some deeper parts of the basin existed planktonic association dominated by planktonic genera *Orbulina* and *Globigerina*, with rare occurrence of index species *Velapertina indigena*.

The Late Badenian/Sarmatian boundary is characterized by disappearance of all planktonic species, and marine reef organisms. Sarmatian sediments (TB 2.6, 3rd order sequence) are characterized by benthic foraminiferal assemblages dominated by *Elphidium*, *Ammonia* and *Anomalinoides*.

Overlying Sarmatian sediments are white-gray calcareous marl of Lower Pannonian without marine microfossils.

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BRYOZOAN-MICROBIALITE REEFS OF THE SARMATIAN (MIOCENE) AND ZECHSTEIN (PERMIAN): A BIOTA COMPARISON

Paweł Raczyński[1,*], Urszula Hara[2], Marek Jasionowski[2], Peryt Tadeusz[2] & Krzysztof Chłódek[3]

[1] University of Wrocław, Institute of Geological Sciences, Pl. Maksa Borna 9, 50-205 Wrocław, Poland
[2] Polish Geological Institute – National Research Institute, 00-975 Warszawa, Poland
[3] Polish Oil and Gas Company, Zielona Góra Branch, Zielona Góra, Poland

*corresponding author: pawel.raczynski@uwr.edu.pl

Co-occurrence of microbialites and bryozoans is not very common in the Phanerozoic sedimentary record. In the Upper Permian Zechstein Limestone (Ca1) and the Sarmatian characteristic carbonate buildups constructed by microbial-bryozoan associations occur. Our goal is to compare the bryozoan role from these distant in time, but similar in many respects, structures.

Bryozoans in the Permian reefs are dominated by stenolaemates of the order Trepostomida and Fenestellida. Their abundance, taxonomical and morphological diversity make them the ubiquitous inhabitants of carbonate bioherms and main framework organisms of the shallow-marine Zechstein limestone (Wuchiapingian) of the Southern Permian Basin. The bryozoans together with the microbialites form the largest part of the reef sediments both in the isolated reefs buildups in the basin facies (e.g., PERYT et al., 2012) and in the marginal carbonate platform facies (e.g., HARA et al., 2013). Several biofacies can be distinguished in the reef sequence, most of which are based on the different colony forms of bryozoans. An example is the Jabłonna reef where five biofacies, such as *Acanthocladia*, then mollusc-crinoid, brachiopod-bryozoan, *Rectifenestella* and stromatolite, have been distinguished. They represent a cycle, which correspond with the shallowing of the sea (PERYT et al., 2016).

In the Lower Sarmatian serpulid-microbialite reefs in the Central Paratethys (Austria, SE Poland, Ukraine, Moldova) the bryozoans are widely distributed, similarly as they occur in the Zechstein (Ca1) basin. The most conspicuous, multilamellar bioconstructions as well as small, dome-shaped or laminar structures are built by *Schizoporella tetragona.* Their morphotypes can be correlated with various environmental factors such as water depth, substrate, water energy and sedimentation rate. The domination of membraniporiform as well the celleporiform colonies in the Paratethys suggests the shallow marine setting moderate to high energy environment and relatively slow sedimentation rate (HARA, 2016).

The most common colony growth-forms in the Zechstein reefs are the fenestrate and branched-pinnate colonies, whereas in the Sarmatian prevail the membraniporiform and celleporiform ones (HARA, 2016). In spite of the substantial differences in taxonomy and morphology between the Permian and the Sarmatian reefs, the bryozoans are the main framework organisms, common bafflers and binders and producers of the detrital sediments among the reef biota.

The different geological history in time and scale of the Zechstein (Ca1) and Paratethys basins strongly suggests that bryozoans have played the important role as a main bioconstructors in the microbialite reef biota. They thrived successfully in the Zechstein and the Sarmatian reefs in spite of the ecological crisis (changes in salinity) resulted in the reduced biodiversity at the end of the Zechstein Limestone deposition time and in the Sarmatian.

Despite a significant taxonomic and morphological differences of both biota they generated very similar reefs. This shows that bryozoans were able to cope in the spatially restricted, geologically short-term settings of Ca1 and in the Sarmatian.

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TECTONO-LITHOSTRATIGRAPHIC MODEL OF THE NORTHERN BANAT MIOCENE SEDIMENTS (PANNONIAN BASIN, SERBIA)

Dejan Radivojević* & Ljupko Rundić

University of Belgrade, Faculty of Mining and Geology, Department of Regional Geology, Kamenička 6, 11000 Belgrade, Serbia

*corresponding author: dejan.radivojevic@rgf.bg.ac.rs

The Neogene back-arc Pannonian Basin lies in southeastern Europe and extends over several countries. The area of interest represents the most attention-grabbing part of Pannonian Basin in Serbia due to its hydrocarbon potential as well as for complex geology and presence of deepest depressions. The hydrocarbon exploration in this area is almost 70 years old which led to large amount of high quality data. At the other side, still there are very limited amount of published papers with couple of exceptions in last decade (STOJANOVIĆ et al., 2007, JELENKOVIĆ et al., 2008, ŠOLEVIĆ et al., 2008, RADIVOJEVIĆ et al., 2010, PIGOTT & RADIVOJEVIĆ, 2010, MATENCO & RADIVOJEVIĆ 2012, MAGYAR et al., 2013).

The database consisted of numerous seismic data, both 2D and 3D, and exploration wells data allowed building of subsurface model of explored area. Special emphasis was placed on the Miocene sediments which are the most valuable part of sedimentary cover due to its economic significance.

The extension of the Pannonian Basin has not occurred simultaneously throughout the area, and it is possible to speak only about synrift and postrift stage in the broader sense (MATENCO & RADIVOJEVIĆ, 2012). In the Serbian northeastern part of Pannonian Basin, sediments of the Lower and Middle (Badenian and Sarmatian) Miocene are assigned to synrift stage. The exemption is Srpska Crnja depression, where synrift phase is somewhat younger and correspond to the Upper Miocene (Pannonian).

The fossil remains are completely absent in Lower Miocene sediments which lies directly below well documented Middle Miocene, and their age was generated based on the analogy with the neighboring areas. The Badenian sediments are mostly represented with its lower part while middle and upper stages are confirmed just on the couple of wells. The thickness of the siliciclastic, carbonate and volcaniclastic sediments is a few dozen meters, while toward the south Badenian sediments becomes considerable thicker (RADIVOJEVIĆ, 2014). Sarmatian sediments are much less present then Badenian one and could be found in a very limited area. Generally, these sediments are very thin and represented with siliciclastics and limestones.

The Pannonian, Pontian, Pliocene and Quaternary sediments belong to postrift stage in the broader sense and lays unconformably over the Middle Miocene. A division of Miocene sediments is straightforward until its upper part. Sediments deposited at time of Lake Pannon, based on the stratigraphic division of the Central Paratethys, belong to the Pannonian and Pontian stage (*sensu* Stevanović). Due to delta progradation from the northwest direction toward southeast, these sediments are younger in Serbia than in neighboring Hungary (MAGYAR et al., 2013, RADIVOJEVIĆ, 2014, RADIVOJEVIĆ & RUNDIĆ, 2016). The sedimentation of the Upper Neogene in the Pannonian Basin for long has been poorly understood because the lithostratigraphic units were correlated and interpreted in chronostratigraphic sense. At the investigated area Pannonian sediments can be roughly correlated with the Hungarian Endrőd and Szolnok formations, while Algyő and Ujfalu formations are correlated with the Pontian deposits. Those fluvial-deltaic deposits make up the largest portion of the sediments which filled this part of Pannonian Basin.

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MODELING OF ECOLOGICAL CONDITIONS IN THE EUXIN BASIN IN THE LATE SARMATIAN AND MAEOTIAN BY METHODS OF DIATOM ANALYSIS

Eleonora Radionova

Russia Geological Institute RAS, Pyzhevskiy per. 7, Moscow, 119017, Russia

radionova@ginras.ru

Modern diatom associations of the Black Sea have more than 30% of the species known in the Sarmatian and more than 20% the common ones with Maeotian. Therefore, the study of the ecological distribution of modern diatoms of Black Sea provides an opportunity to understand the ecology of the Neogene Euxin basin (NEB).

Along the Black Sea coast, several ecological areas have been identified based on the composition and abundance of diatom (PROSHKINA-LAVRENKO, 1955, 1963). We are most interested in 1. Eastern area 2. Kerch area 3. North-western area, differing in hydrology, type of shore, composition of soils. For each area, we can find diatoms-indicators of local conditions. Their presence allows us to model some of the sarmatian-maeotian environments of NEB.

1. The Eastern area covers the coast from Anapa to Batumi, characterized by rocky shores and narrow sublittoral. Here is constant salinity (18 ‰) and one can see influence of the Bosporus current. Plankton is not rich: *Coscinodiscus janischii*, *Thalassiosira antiqua*, *Rhizosolenia* sp., *Chaetoceras* sp. In coastal plankton there are *Rhabdonemma adriaticum*, *Hyalodiscus ambiguous*, warmwater *Actinoptychus undulatus*, *Asteromphalus robustus*, *A. flabellatus*.

Lower Maeotian Diatom associations of NEB are similar to that of the Eastern area. We can model environmental conditions for the Maeotian as semi-marine, close to the Mediterranean by temperature. The composition of benthic diatoms indicates a rocky coast.

2. Kerch area is located between Anapa and Theodosia. Through the Kerch Strait, the basin is connected with the Sea of Azov. The currents, salinity are variable. This shallow-water area with silty soils is represented by bays and limans, the waters of which have a different salinity. Due to the inflow of the waters of the Azov Sea, Kerch Strait Diatoms are numerous brackish benthic *Synedra tabulata*, *Rhopalodia gibberula*, *Amphora coffeiformis* and others. There are *Diploneis bombus*, *Surirella fastuosa*, *Nitzschia punctata* at the bottom. The plankton species carried by the Azov waters are *Coscinodiscus gigas*, *C. granii*, *Thalassiosira decipiens*, *Th. excentrica*, brackish water *Thalassiosira parva*, *Th. minima*, *Sceletonema costatum*. Among the species introduced into the Sea of Azov from the Black Sea, the main ones are *Proboscia alata*, *Pseudosolenia calcar-avis* and *Nitzschia reserve* (KOVALEVA, 2006).

The peculiarities of the Kerch region are the dominance of brackish-water benthos and the appearance planktonic Azov Sea species. Particularly interesting is the genus Thalassiosira. Marine *Thalassiosira decipiens*, *Th. excentrica* here live at a salinity of less than 18‰. Azov Sea *Thalassiosira parva*, *Th. minima* live at a salinity 7-10‰. This **association of Thalassiosira** is an indicator of the unstable ecological situation in the Kerch Strait. Their appearance can be considered as a **marker of water exchange** in the Black and Azov Seas. The same **Thalassiosira** is found in the **Lower Maeotian** of NEB.

3. The north-western area is located from mouth of the Dnieper to mouth of the Danube. This is a shallow shelf with a flat silty bottom. Due to river runoff, salinity of this area ranges from 5.3 to 16 ‰. The brackish-water diatoms constitute about 30% of the plankton. *Detonula confervaceae*, *Th. subsalina*, *Coscinodiscus jonesianus* dominate. In plankton association *Thalassiosira coronata*, *Th. Subsalina* are markers of significant desalination. Benthos is extremely rich. Fouling brackish water *Achnantes brevipes*, *Synedra tabulata*, *Amphipleura rutilans*, *Cocconeis pediculus* are dominated. *Diploneis ovalis*, *Navicula* sp., *Amphiprora paludosa*, *Nitzschia apiculata* are often found on the bottom.

The composition of the benthic and planktonic associations of diatoms more than 50% coincides with that of the **middle-upper transition Sarmatian of NEB** when *Achnantes brevipes* becomes dominant in the benthos association and *Thalassiosira coronata* first appears in the plankton composition.

THE KONKIAN SEDIMENTARY REGIME IN THE EASTERN PARATETHYS (TAMAN REGION)

Yuliana Rostovtseva[1,*], Alexandra Rylova[1] & Alena Rybkina[2]

[1] Lomonosov Moscow State University, Faculty of Geology, Leninskie Gory St. 1, 119991 Moscow, Russian Federation

[2] Geophysical center of the Russian Academy of Sciences, Molodezhnaya St. 3, 119296 Moscow, Russian Federation

*corresponding author: rostovtseva@list.ru

In Eastern Paratethys, the Konkian regional stage is correlated to the uppermost of the Badenian in the Central Paratethys and the lower part of the Serravallian in the Mediterranean (HILGEN et al., 2012). Sarmatian sediments directly overlie the Konkian sequence. The Konkian-Sarmatian boundary is considered equivalent of the Badenian-Sarmatian boundary (STUDENCKA & JASIONOWSKI, 2011; POPOV et al., 2013). Lower boundary of the Sarmatian is estimated as 12.7 Ma for the Central Paratethys (PILLER et al., 2007; HILGEN et al., 2012). Marine transgression at the beginning of the Konkian led to increased salinity of water to 30‰ in the Eastern Paratethys.

We have focused our research on the Konkian sediments in Zelensky-Panagia section. The Zelensky-Panagia section is located on the Black Sea coast of Taman Peninsula (Eastern Paratethys) (N45°13'54.5" E36°65'23.2", Russia) and comprises well-exposed upper Chokrakian-Maeotian sediments. In this section, the total thickness of Konkian sediments is approximately 28 m. The Konkian sediments of the Taman Peninsula were accumulated in relatively deep-water environment (at depths ranging from 100 to 150 m). The studied deposits are mainly clays with sporadic carbonate layers. Our study showed that there are two types of carbonate layers in Konkian sediments related to the different sedimentary regimes. The first type of carbonate layers consists of calcareous nannoplankton (Figure 1). The second type of carbonate layers is the microbial mat reflecting the decrease in clay sedimentation rate. We found the several microbial carbonate layers (up to 0.15–0.25 m) in the Konkian sediments.

In this study the Konkian sediments were investigated by cyclostratigraphic methods using the magnetic-susceptibility rocks and statistical techniques. In the studied interval, spectral anal-

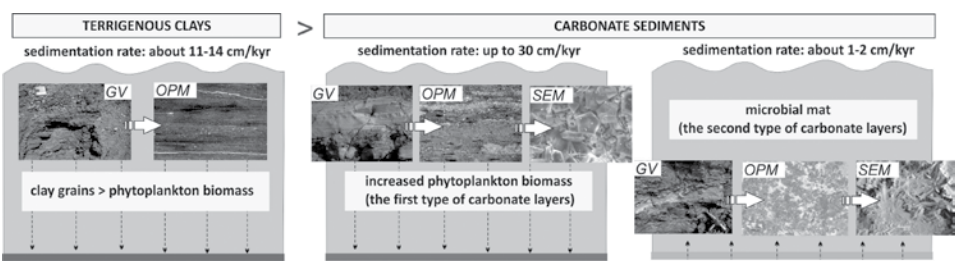

Figure 1. The Konkian sedimentary regime in the Eastern Paratethys (Zelensky-Panagia section, Taman Region). The general view of sediments (GV), the thin section (OPM), the scanning electron microscope image (SEM).

ysis revealed statistically significant signals with 14.2 m and 2.1–3.3 m wavelength. These signals correspond to the 100-kyr eccentricity and precession cycles, respectively. Our results allowed calculation of the average sedimentation rate. The average sedimentation rate was estimated as 11.4–14.2 cm/kyr for the Taman Konkian. The duration of the Konkian can be estimated as 0.2–0.25 Myr without taking into account the sedimentation rate for the carbonate layers.

Based on the obtained results we can suggest that the change from normal to reversed polarity in the lower part of the Eastern Paratethys Konkian (MOLOSTOVSKY & CHRAMOV, 1997; GREBENYUK, 2004) relates to the Chron C5AAn/C5Ar.3r boundary. The duration of the Konkian can be estimated as 0.35–0.45 Myr.

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MIO-PLIOCENE GEODYNAMICS AND ITS STRATIGRAPHIC CONSEQUENCES IN THE AREA OF AVALA MT. (BELGRADE, SERBIA)

Ljupko Rundić*, Meri Ganić, Slobodan Knežević & Dejan Radivojević

University of Belgrade, Faculty of Mining and Geology, Department of Regional geology, Kamenička 6, 11000 Belgrade, Serbia

*corresponding author: ljupko.rundic@rgf.bg.ac.rs

In recent years, thanks to numerous infrastructural works and construction of the local roads, new outcrops and sections near Avala Mt. have been discovered. Especially, on the left bank of the Rakovica stream, a new large outcrops have been studied. For example, a completely new, long section (> 150 meters) of the Lower Sarmatian sand, silty clay, sandstone and marly limestone is observed for the first time. In addition, the coarse-grained clastics from the basal part of Miocene which indicates well-known the Middle Miocene Badenian transgression are noticed. They lie over the reddish fluvial facies of the undivided Lower Miocene. Besides, a lot of new data are obtained from the previously known stratigraphic units (Pannonian and Pontian, sensu Stevanović). Based on litho- and biostratigraphic analysis and measurement of basic structural elements of each units throughout the area, the obtained data were correlated with the results of two earlier drilled wells (KGK-13 and KGK-14) in the Rakovica stream valley (KNEŽEVIĆ, 1989). The resulting stratigraphic data are interpreted in the context of Neoalpine geodynamics and revealed a complex tectonic structure with pronounced block structures. In the studied area, during the Neoalpine tectonics the significant differential movement (uplift/downthrown) was present that have shaped today's relief of the area (MAROVIĆ et al., 2007). The Torlak hill represents horst structure with a core of Mesozoic rocks and wings made of Badenian and Sarmatian sediments (EREMIJA, 1977; STEVANOVIĆ, 1970). Downstream of the Avala – Belgrade road, in the middle course of the Rakovica stream, near to the Rakovica village, there is a small tectonic trough, which is a branch of a large the Beli potok trough which is filled with sediments of the upper Miocene (Pannonian and Pontian) and partly the part of middle Miocene -Sarmatian.

The Torlak horst and the Beli potok trough structures are separated by the fault zone known as the Rakovica fault. These geological structures are noted for their large vertical movements along that fault line, at some places more than 200 meters. For example, in the KGK 14 well, just below the Pontian sand, the Pannonian marl on the absolute height of less than 100 meters was discovered. However, only a few hundred meters away in the northeast direction, at the foot of the Torlak hill, same Pannonian marl are found on surface at an altitude of about 210 meters. At the same time, at top of the Torlak hill, Badenian sediments are present on the surface at altitudes of around 336 meters. Tectonic movements have been occured during the Late Miocene and Pliocene and probably in the older Pleistocene. Due to the mentioned vertical movements along the block structures, a composite hilly relief with dominant the Torlak hill and the Beli potok valley was formed.

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THE MIDDLE MIOCENE DEPOSITS OF THE NORTHERN GABČÍKOVO-GYÖR DEPRESSION (DANUBE BASIN)

Samuel Rybár[1,*], Michal Kováč[1], Andrej Ruman[1], Natália Hudáčková[1], Eva Halásová[1], Michal Šujan[1], Marianna Kováčková[1] & Katarína Šarinová[2]

[1] *Comenius University in Bratislava, Faculty of Natural Sciences, Department of Geology and Paleontology, Mlynská dolina, Ilkovičova 6, 842 15 Bratislava, Slovakia*

[2] *Comenius University in Bratislava, Faculty of Natural Sciences, Mlynská dolina, Ilkovičova 6, 842 15 Bratislava, Slovakia*

*corresponding author: samuelrybar3@gmail.com

The Danube Basin is situated between the Eastern Alps, the Central Western Carpathians and the Transdanubian Range. It represents the north-western sub-basin of the Pannonian Basin System. The central part of the sub-basin is referred to as the Gabčíkovo-Györ depression and it embodies the largest depocenter of the basin with total sediment thickness of about 7000 m (HRUŠECKÝ, 1999; KOVÁČ, 2000; HORVÁTH et al., 2015). Sediments occurring in the central part of the depression are partly underexplored and the depositional systems are still not fully understood. This is due to the scarce 2D reflection seismic grids and poor coverage by deep wells (especially in the Northern parts). To tackle this problem we revised the existing well and geophysical data-set, what led us to the conclusion that the middle Miocene sediments onlap discordantly onto the late Paleozoic crystalline rocks, which belong to the Tatric unit in the West and to the Veporic unit in the East. The South-eastern marginal part belong to the Transdanubian range unit FUSÁN et al., (1987). The seismic facies of the Tatric and Veporic crystalline rocks are discontinuous and characterized low amplitudes and low frequencies. Unfortunately, none of the available seismic lines cuts through the Transdanubian range. Nonetheless Paleozoic, Mesozoic and Paleogene rocks of this unit are well known from many deep wells BIELA (1978). In the central part the Lower Badenian/Karpatian (Langhian/upper Burdigalian) volcanic and volcano-clastic deposits (PECSKAY et al., 2006) seem to onlap discordantly right onto the crystalline rocks. The seismic facies of these rocks are discontinuous, and display high amplitudes and low frequencies. This facies are best imaged on the MXS2/93 where the concave shape of the Králová stratovolcano is properly recognizable (HRUŠECKÝ, 1999). The presence of these rocks is additionally confirmed by the Kráľová-1 well (BIELA, 1978). The upper Badenian (lower Serravallian) rocks onlap discordantly either onto the basement rocks or onto the lower Badenian (Langhian) volcanic rocks. The seismic facies of the upper Badenian deposits are continuous with high amplitudes and medium frequencies. These facies are mostly horizontal with an exception of the line MXS6/93 where a prograding configuration is observed. The clinoform height varies around ~ 400 ms (TWT). These sediments were additionally confirmed by Diakovce-1 well (BIELA, 1978). The upper Miocene-Pliocene sequence onlaps mostly discordantly onto the middle Miocene deposits and forms the main mass of the basin-fill. It includes the standard lacustrine, deltaic and alluvial succession described in detail by ŠUJAN et al., (2016) and SZTANÓ et al., (2016).

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STRUCTURAL EVOLUTION OF THE MECSEK–VILLÁNY AREA (SW HUNGARY) DURING POST-RIFT PHASE AND BASIN INVERSION

Krisztina Sebe

University of Pécs, Department of Geology and Meteorology; 7624 Pécs, Ifjúság ú. 6., Hungary

sebe@gamma.ttk.pte.hu

The beginning of the neotectonic period, the shift from the thermal subsidence to basin inversion, plus younger neotectonic activity has been investigated in the past years in SW Hungary, in uplifted basements blocks of the Mecsek–Villány area. Here syn-tectonic sediments were available to conserve signs of tectonic movements. The main points were: to identify and date tectonic events; to temporally and spatially constrain flooding of the area by Lake Pannon, to distinguish climatic and tectonic effects in relative lake level changes; and to reveal the uplift history of the presently uncovered basement. The work resulted in a detailed picture of structural evolution of the area, discerning new deformation phases. A revised bio- and lithostratigraphy was compiled for the Late Miocene (Pannonian), making it possible for the first time to tie dates to tectonic events. The evolution history of the study area based on the new research is summarized here.

At the beginning of the post-rift period the (post-)Sarmatian inversion was the first important event, which resulted in an increase of relief, probably related to large-scale folding and also thrusting. While offshore sedimentation seems to be continuous across the Sarmatian-

Pannonian boundary in (sub)basin centres, most areas show a hiatus and unconformity increases towards the mountains.

Sedimentation – with open-water calcareous marls – resumed around 11 Ma in the transitional area between the Mecsek and Villány Hills and in the immediate foreland of the Mecsek; macroflora indicated elevated topography near the lakeshore. The mountains remained subaerial until the latest Pannonian, ~8-7 Ma. During the post-rift period generally characterized with thermal subsidence and plastic deformation, important marginal fault zones in the area were active and produced brittle deformation. Within the Pannonian, at least three tectonic events can be distinguished, a transtensional and two compressional/transpressional ones, with deformation mostly localized along the mentioned fault zones. Signs of extension/transtension were only recorded in the oldest (11-10 Ma) sediments. Compression (N-S) ensued already in the same biochron, before 10 Ma.

Flooding of the mountains by Lake Pannon happened during a very short time period, practically coevally in the whole area (8-6.5 Ma). Burial by the Lake Pannon delta system occurred shortly after the transgression along the mountain range, invoking a linkage between the two phenomena.

Shortly after the transgression, intense compressional (transpressional) tectonics started all over the study area, which can already be linked to the basin inversion. From then on until the complete filling up of Lake Pannon in the area (~6.5 Ma), a complicated interplay of relative lake level changes and tectonic movements, much more complex than in basin areas, controlled sedimentation.

After the Pannonian, reverse and strike-slip faulting continued. Uplift of the Mecsek Mts. seems to have been less (a few tens of m-s to a few hundred m-s) than previously estimated. Young Quaternary uplift rates are at the order of 0.01 mm/y in the west. Deeply incised modern valleys can be at least partly results of repeated filling and re-incision during glacial and interglacial periods. Fractured clasts provided evidence of seismic shocks in the Mecsek during the Pleistocene. In the Villány Hills, the majority of the post-Pannonian uplift must have happened before 3 Ma, Quaternary uplift rates are low (max. 0.05–0.01 mm/y).

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RED JASPER OCCURRENCE IN SREBRNJAK HILL, SAMOBORSKO GORJE MT. AS INDICATION OF POSSIBLE VOLCANIC ACTIVITY

Željka Sladović[1,*] & Vesnica Garašić[2]

[1] *Geoda Consulting d.o.o., Zvonimirova 13, 10000 Zagreb, Croatia*
[2] *University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering, Pierottijeva 6., 10000 Zagreb, Croatia*

*corresponding author: zeljka@geoda.hr

The abundant occurrence of red jasper in yellow to pale clayish sediment in Srebrnjak hill at the eastern edge of Samoborsko gorje Mt. has induced petrographic and geochemical researches. The Miocene layer that VRSALJKO (2003) classified as Andraševci member is overlain by the yellow to pale clayish sediment.

The jasper samples found in the sediment depths of 1 to 2 m are characterized by well-defined semi-flat faces.The samples that differ in colour have similar structure (Figure 1) showing kidney like outgrowth on the largest plate. The jasper is in sediment associated with irregular quartz boulders, feldspar, goethite geodes and rhyolite cobbles.

In order to find out if the jasper could have volcanic origin petrographic and geochemical investigations of associated rhyolite cobbles were performed.

The petrographic study has revealed that the rhyolite cobbles have porphyritic texture with rare phenocrysts and simple mineral assemblage. It comprises coarse K-feldspar (mostly sanidine) and plagioclase phenocrysts in the fine-grained matrix consisting mostly of quartz, feldspar and tiny chlorite and opaque minerals. Feldspar phenocrysts are partly replaced by sericite and clay minerals, and locally also by calcite. The ferromagnesian phenocrysts do not occur, but their replacement chlorite aggregates and Fe-oxides are present. Zircon and apatite are accessory phases, randomly distributed in the fine-grained matrix. Occasionally some coarser opaque grains are found, too. The studied samples were classified as rhyolite on the basis of petrography.

Geochemical analyses are used for chemical classification of rhyolite cobbles, both on the basis of main and trace elements. In TAS diagramms samples are plotted in rhyolite field, whereas in Zr/Ti-Nb/Y diagram after PEARCE (1996) they are situated in rhyolite/dacite field. Geo-

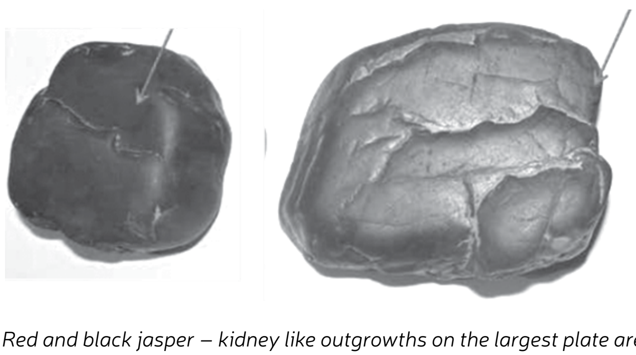

Figure 1. Red and black jasper – kidney like outgrowths on the largest plate are marked with red arrows.

chemical studies indicated calc-alkaline nature of these volcanic rocks. Their spieder diagrams are characterized by negative Nb-Ta anomaly what is in concordance with their determinated volcanic arc geotectonic position based on their Rb-(Y+Nb) ratio in diagram of PEARCE et al (1984). The REE patterns of this samples, normalized to chondrite, show enriched LREEs in the relation to HREEs and negative Eu anomaly.

Similar main and trace element characteristics show "Southern Volcanos" of Periadriatic lineament described by PAMIĆ & PALINKAŠ (1992).

Therefore, the associated occurrence of rhyolite cobbles and jasper in yellow to pale clayish sediment open the possibility of the existence of felsic volcanism in the investigated area. This is not a new idea. KRAMBERGER (1905) stated that several generations of volcanism occurred nearby main faults during Miocene in this area.

Seismic data set were interpreted with Nedjelja-1 as key well. Miocene Base, Badenian and Sarmatjan Top were interpreted. The paleontological cores analyses (VRSALJKO, 2003) were the base for time determination. Fault sets surrounds and crosses paleo hill onlapped with the horizontal layers (Lower Miocene). Pull-ups (Pontian?) cross uphill. Such setting could confirm Neogene magmatism occurrence.

Already initiated further geophysical investigations of the studied area will give an important additional contribution to resolving the enigma of possible volcano existence in Srebrnjak hill, in Samoborsko gorje Mt.

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BADENIAN/SARMATIAN BOUNDARY IN THE CENTRAL PARATETHYS: DATA FROM THE FORE-CARPATHIAN BASIN IN POLAND

Barbara Studencka, Krzysztof Bukowski[2], Grzegorz Czapowski[3], Andrzej Gąsiewicz[3] & Karin Sant[4]

[1] Polish Academy of Science Museum of the Earth in Warsaw, 00-488 Warsaw, Al. Na Skarpie 20/26, Poland
[2] AGH University of Science and Technology, Mickiewicza 30, 30-059 Krakow, Poland
[3] Polish Geological Institute–National Research Institute; 00-975 Warsaw, Rakowiecka 4; Poland
[4] Utrecht University, Faculty of Geosciences, Paleomagnetic Laboratory "Fort Hoofddijk", Budapestlaan 17, 3584 CD, Utrecht, The Netherlands

*corresponding author: bstudencka@go2.pl

In the deposits of the Central Paratethys basins the Badenian/Sarmatian border has mostly erosional character. The Polish part of the Fore-Carpathian Basin represents one of few areas within the Central Paratethys where sedimentation of monotonous siliciclastic deposits continued throughout the Late Badenian and the Early Sarmatian. The deposit succession of this time interval was distinguished as the Machów Formation.

Two exploratory boreholes: Busko (Młyny) PIG-1 (depth 200 m) and Kazimierza Wielka (Donosy) PIG-1 (depth 191 m), were drilled in the northern margin of the Fore-Carpathian Basin in 2010. The deposits representing the Machów Fm. form the core interval of 34.00–157.00 m in the Busko (Młyny) PIG-1 borehole, and the core interval of 27.30–188.00 m in the Kazimierza Wielka (Donosy) PIG-1 borehole. Under this study they have been widely investigated by complex stratigraphic, petrological, geochemical, palaeomagnetic and sedimentological research.

Calcareous nannoplankton, foraminifera and bivalves have been studied to clarify the Badenian/Sarmatian boundary. Based on calcareous nannoplankton the Machów Fm. represents the NN6 *Discoaster exilis* Zone (GAŹDZICKA, 2015). Within the Machów Fm. strata of the Busko (Młyny) PIG-1 four foraminifera assemblages were identified correlated with: *Neobulimina longa*, *Velapertina indigena* and *Hanzawaia crassiseptata* zones (Late Badenian) and *Anomalinoides dividens* (Early Sarmatian). The *Velapertina indigena* (Late Badenian) and *Varidentella sarmatica* zones (Early Sarmatian) were identified within the Kazimierza Wielka (Donosy) PIG-1 core (PARUCH-KULCZYCKA, 2015). Within the Machów Fm. strata of the Busko (Młyny) PIG-1 ten bivalve species have been identified. Specifically, the pectinid species *Delectopecten vitreus* (Gmelin, 1791) defines the base of the Machów Formation as the Late Badenian while *Abra* (*Syndosmya*) *reflexa* (EICHWALD, 1830) enables to precise the age of the uppermost part of the Machów Fm. as the Early Sarmatian (STUDENCKA, 2015).

Bivalve and foraminifera assemblages define the Badenian/Sarmatian boundary within the depth range of 109.10–117.40 m in the Busko (Młyny) PIG-1 borehole, and within the depth range of 148.30–162.80 m in the Kazimierza Wielka (Donosy) PIG-1 borehole. New faunal assemblages of the Sarmatian type occurred earlier than the geochemistry change in the Machów Fm. sediments (GĄSIEWICZ, 2015).

The observed R–N–R polarity pattern in the Badenian part of the Kazimierza Wielka (Donosy) PIG-1 core profile suggests a tentative correlation to chrons C5AAr–C5Aan–C5Ar.3r of the GPTS, indicating an age of 12.8 ±0.1 Ma (SANT et al., 2015).

Several tuffite thin levels were found in the two drilled cores. First tuffite level just above the evaporites, the most widespread and with characteristic chemical composition of pyroclastic components, can be applied to the regional correlation of Miocene deposits. Second tuffite level is located above a change from normal (C5AAn) to reversed (C5Ar.3r) polarity (BUKOWSKI, 2015) registered at 170 m depth in the core Kazimierza Wielka (Donosy) PIG-1 (SANT et al., 2015).

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NEW DATA ON THE AGE OF THE MACHÓW FORMATION DEPOSITS FILLING THE FORE-CARPATHIAN BASIN IN POLAND: EVIDENCE FROM PRZECŁAW

Barbara Studencka[1,*], Krzysztof Bukowski[2], Arjan de Leeuw[3], Małgorzata Garecka[4], Monika Pilarz[2] & Piotr Witalis[2]

[1] Polish Academy of Science Museum of the Earth in Warsaw, 00-488 Warsaw, Al. Na Skarpie 20/26, Poland

[2] AGH University of Science and Technology, Mickiewicza 30, 30-059 Krakow, Poland

[3] CASP West Building, 181A Huntingdon Road, Cambridge, CB3 0DH United Kingdom

[4] Polish Geological Institute–National Research Institute, Carpathian Branch in Cracow, Skrzatów 1, 31-560 Krakow, Poland

*corresponding author: bstudencka@go2.pl

During the Miocene the Fore-Carpathian Basin in Poland constituted the northernmost part of the Central Paratethys. Through the Late Badenian – Sarmatian its vast territory was filled with fine-grained, poorly consolidated siliciclastic deposits distinguished as the Machów Formation. The thickness of this formation varies from several tens of meters to over 3 km in the south-eastern part of the Fore-Carpathian Basin.

The study has been focused on the determination of the geological age of the uppermost part of the Machów Fm. cropping out at the Przecław brickyard, about 100 km north-east of Cracow. The section at the Przecław brickyard attains a thickness of 20.0 m. Two units can be distinguished on the basis of lithological features and macrofossil content (bivalves and plants). The section begins with a 12 m thick gray laminated clay interval containing very scarce bivalve shells. The upper unit attains a thickness of 6.0 m. It is composed of alternations of greyish clays and yellowish very fine-grained muddy sandstones (less than 2 cm in thickness and rich in mica) with numerous bivalve shells and shell detritus.

Bivalve shells show evidence of post-mortem transport, such as disarticulation and fragmentation. Five bivalve species have been identified. The abundance of the venerid species *Polititapes tricuspis* (Eichwald, 1828) defines the age of these deposits as the latest Volhynian–middle Bessarabian. This species vanished from the entire Paratethys in the Middle Sarmatian s.l., or at the end of the Sarmatian s.s.

Both calcareous nannoplankton and foraminifera are studied to clarify the stratigraphic position of the uppermost part of the Machów Fm. The lower unit yields stratigraphically useful association containing *Discoaster kugleri* Martini et Bramlette indicating the NN7 Zone. An association with *Catinaster coalithus* Martini et Bramlette recorded in the upper part of this unit documents the NN8 Zone. A preliminary study of foraminifers has shown that the lower unit can be referred to the *Elphidium hauerinum* Zone and the upper unit probably corresponds to *Protelphidium subgranosum* Zone (CZEPIEC, 1996). Moreover, in the upper part some specimens of thecamoebians genus *Silicoplacentina* have been recognized which suggest latest Volhynian–Bessarabian age (PARUCH-KULCZYCKA, 1999).

A preliminary paleomagnetic study has shown that the investigated clays from the lower part of the quarry were deposited in a reversed polarity chron. In the upper part of the profile, the polarity is reverse, but vector diagrams additionally show a residual, high field component that is normal. This could indicate proximity to a normal chron at the top of the quarry.

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MICROPALEONTOLOGICAL STUDY OF THE MIDDLE MIOCENE SECTION CIPROVAC, DILJ MT.

Monika Špišić[1,*], Koraljka Bakrač[1], Valentina Hajek-Tadesse[1], Radovan Filjak[1], Mihovil Brlek[1], Radovan Avanić[1], Ines Galović[1] & Mirjana Miknić[2]

[1] *Croatian Geological Survey, Department of Geology, Sachsova 2, HR-10000 Zagreb, Croatia*
[2] *Bartolići 49, 10 000 Zagreb, Croatia*

*corresponding author: mspisic@hgi-cgs.hr

Section Ciprovac is situated in central part of Dilj Mt., in the vicinity of quarry Zdenci. With a thickness of 73 m represents distal, deep-water equivalent of mentioned quarry with traceable changes in micropaleontological assemblages from lower Badenian to Sarmatian.

The basal part of the section is represented by coralline limestones with abundant cross-sections of *Elphidium* sp., *Amphistegina* sp., *Planostegina* sp. and scarce cross-sections of miliolids, *Eponides repandus* and planktonic foraminifera. Coralline red algae are represented by rhodolites with ingrown *Acervulina sp.* All mentioned characteristics are comparable with Leitha Limestone (REUTER et al., 2012) so we consider them as time equivalents (REUTER et al., 2012.; HOHENEGGER et al., 2014). Early Badenian age (HOHENEGGER et al., 2014) is also confirmed by planktonic foraminifera assemblage found in marls above: *Praeorbulina glomerosa circularis*, *Globigerinoides bisphericus* together with *Praeorbulina sicana*.

Middle Badenian, according to HOHENEGER et al. 2014., is represented by "warm water" fauna of Lower Lagenidae Zone and "slightly cooler but still warm fauna" of upper Lagenidae zone together with co-occurrence of *Praeorbulina glomerosa circularis* and *Orbulina suturalis* (HOHENEGGER et al., 2014). Foraminiferal assemblage composed of benthic *Lenticulina echinata*, *Planularia moravica*, *P. lanceolata*, *Vaginulina legumen*, *Vulvulina pennatula*, *Fontbotia wuellersdorfi*, *Orthomorphina columella*, *Bolivina scalprata retiformis*, *Dimorphina akneriana, Lingulina costata* and planktonic *Globorotalia woodi*, *Paragloborotalia acrostoma*, *Globigerinoides altiapertura*, *Globigerinoides sacculifer* together with *Praeorbulina glomerosa circularis* and *Orbulina suturalis* are characteristic for former Moravian (CICHA et al., 1998.), present middle Badenian (HOHHENEGER et al., 2014.). According to RYBAR et al., 2015. Badenian has two stages (early and late Badenian) so the co-occurrence of *Globigerinella regularis*, *Globigerinoides quadrilobatus* together with *Orbulina suturalis* points to NN5 zone and it's attributed to early Badenian what corresponds to middle Badenian of HOHENEGGER et al., 2014. in their three stages subdivision.

Nowadays upper Badenian (HOHENEGGER et al., 2014.) is composed of former Wielician (zone of agglutinated foraminifera) at the base, and Kosovian (Bulmina-Bolivina zone) in the upper part. The abundance of *Lenticulina ariminensis* and *Bolivina vienensis* together with *Uvigerina semiornata*, *U. aculeata* and *U. ex gr. pudica-asperula* and planktonic foraminifera *Orbulina universa* and *Globoturborotalita druryi* are characteristic for Wielician. RYBAR et al., 2015. assume that appearance of *Globoturborotalita druryi* coincides with NN5/NN6 boundary. Kosovian is marked by the occurrence of *Pappina neudorfensis* and *Velapertina indigena* within the foraminiferal assemblage. In Ciprovac section samples with abundant small tenuitellids (*Tenuitellinata angustiumbilicata, Turborotalia selleyi, Turborotalia neominutissima, Globigerinita glutinata*) occur and can be attributed to Tenuitellinata Zone of FILIPESCUE & SILYE (2008). Transition to Sarmatian can be traced via changes in fossil assemblage e.g. increase portion of *Porosononion granosum* and dominance of nanoplankton *Reticulofenestra pseudoumbilica* over *Cyclicargolithus floridanus* points to Badenian/Sarmatian boundary.

Base of Sarmatian is documented by the appearance of *Elphidium reginum* and *Anomalinoides cf. badenensis/dividens*. In other samples, besides reworked Badenian benthic and planktonic foraminifera, *Elphidium aculeatum*, E. *hauerinum*, *E. rugosum*, *E. grilli*, *E. joukovi*, *Nonion tumidulus*, *N. biporus* and sarmatian bolivinids occur together with small tenuitelid foraminifera and *Streptochilus* sp.

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PLIOCENE TO QUATERNARY ALLUVIAL DEPOSITIONAL SYSTEMS OF THE NORTHERN DANUBE BASIN: APPLICATION OF THE ^{10}Be/^{26}Al BURIAL DATING METHOD ON BOREHOLE SAMPLES

Michal Šujan[1,*], Régis Braucher[2], Michal Kováč[1], Samuel Rybár[1], Andrea Schittenhelm[1], Juraj Maglay[3], Klement Fordinál[3] & Alexander Nagy[3]

[1] Comenius University in Bratislava, Faculty of Natural Sciences, Department of Geology and Paleontology, Ilkovičova 6, 842 15 Bratislava, Slovakia

[2] Aix-Marseille Université, CEREGE, CNRS UM 34, F-13545 Aix-en-Provence, France

[3] Dionýz Štúr Institute of Geology, Mlynská dolina 1, SK-817 04 Bratislava, Slovak Republic

*corresponding author: miso@equis.sk

The Danube Basin represents one of the major depocenters of the Pliocene to Quaternary age in the Carpathian-Pannonian region, with thickness of corresponding alluvial sandy-gravelly succession reaching 500 m (MAGLAY et al., 2009). These deposits serve as a groundwater resource of European importance and the area is densely inhabited. However, the age of the sequence in question is still a conundrum, what left many issues regarding the neotectonic activity and geohazards in the area unresolved. Purpose of the presented study is to fulfil this lack of geochronological data.

The ^{10}Be/^{26}Al burial dating method was applied to 10 gravelly samples taken from borehole cores with depths ranging from 6 to 217 m. The method is based on the stable production ratio 1:6.75 of both cosmogenic radionuclides in a quartz grain exposed on the surface. After being buried by successive deposition, a sample is shielded from cosmic rays and ratio of ^{10}Be and ^{26}Al concentrations changes proportional to time of their burial due to different half lives (e.g., GRANGER & MUZIKAR, 2001).

Obtained results vary from 0.5 to 3.2 Ma. They indicate continual deposition across the Pliocene-Quaternary boundary up to the Middle Pleistocene, without significant hiatus. Aggradation rates show low values, which are realistic in comparison with published data (COLOMBRERA et al., 2015), as well as to analogous braided river depositional environments (e.g., MEDICI et al., 2015). Taking into account progressive increasing of aggradation rates towards the central part of the basin and continual deposition, we have to consider compaction of the underlying upper Miocene sequence as a cause of the subsidence. Gravelly strata on the basin margin near Bratislava yielded relatively high – Middle Pleistocene age, what indicates condensed deposition. The upper Miocene succession was partly eroded there during the basin inversion, thus this succession is overcompacted on the basin margin and it did not contribute to the accommodation during the Plio-Quaternary period. This scenario was indicated also by the study of geotechnical parameters of foundation soils in the area (ŠUJAN et al., 2016). Obtained results imply that tectonic activity is not necessary for explanation of subsidence and its lateral variability in the Danube Basin during the neotectonic period.

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DEPOSITIONAL MODEL OF EARLY AND MIDDLE MIOCENE SEDIMENTS IN THE OIL FIELD BUNJANI, SAVA DEPRESSION

Jasna Tadej[1,*], Željka Marić Đureković[2], Vlasta Premec Fućek[3] & Marina Mužina[4]

[1] INA – Industrija nafte, d.d., Exploration Sector, Rock & Fluid Analysis Department, Av. Većeslava Holjevca 10, Zagreb, Croatia

[2] INA – Industrija nafte, d.d., Field Development Sector, Formation Evaluation Department, Av. Većeslava Holjevca 10, Zagreb, Croatia

[3] INA – Industrija nafte, d.d., Exploration Sector, Rock & Fluid Analysis Department, Lovinčićeva 4, Zagreb, Croatia

[4] INA – Industrija nafte d.d., Exploration sector, Geology & Geophysics Department, Av. Većeslava Holjevca 10, Zagreb, Croatia

*corresponding author: jasna.tadej@ina.hr

Bunjani oil field belongs to the northeast edge of the northwestern part of the Sava Depression and represents the slope of Moslavačka gora Mt. affected by intense extension tectonics.

On the basis of petrographic and biostratigraphic well data, well log analyses and interpretation of 3D seismic, facies analysis was performed, depositional environments were defined and depositional evolution was reconstructed.

Studied Early and Middle Miocene sediments (Prečec Formation) are characterized by significant facies diversity as a result of indented geomorphology of pre-Miocene basement, synsedimentary tectonics and global sea level changes.

Neogene sedimentation most probably started during Early Miocene. Along the slopes and in the foot of uplifted massif coarse grained detritus was accumulated as rockfalls/debris or in the proximal parts of alluvial fans in subaerial conditions. This unsorted breccias and conglomerates of monomict composition are formed in syn-rift tectonic phase by erosion of uplifted footwall basement blocks, short transport of eroded material in depocenters formed in hanging-wall blocks.

Marine transgression started in Badenian and gradually affected deposition in the whole area of Sava depression. In the Bunjani area fan deltas were formed with deposition of thick sequences of breccia-conglomerates and lithic sandstones with marl intercalations. Presence of Badenian benthic and planktonic foraminifera in marl intercalations indicates shallow marine environment, steep relief, erosion of uplifted highs and redeposition along basin margins into marine shelf.

In southern part of the field deeper marine environment existed, where fine grained sediments with predominantly planktonic foraminifera were deposited. Thin sandstone intercalations are result of mass flows and transport of siliciclastic detritus to basinal area. Lower to Middle Badenian age was determined according to characteristic association of foraminifera.

In northern part of field deposition took place on shallower shelf environment with open marine influence. Conglomeratic sandstones and marls with limestone intercalations prevail. Abundant benthic fossils and presence of bioclastic detritus indicate shallow marine environment, while increase of planktonic forms in some levels refer to sea level oscillations.

Upper Badenian sediments were determined in few wells. Calcareous marls, marly limestones and calcarenaceous sandstones were deposited in restricted shallow marine environment.

Sarmatian sediments were not paleontological documented due to small thickness and rare sampling, but according to well log analysis continuity in deposition from Badenian to Sarmatian and Pannonian in some wells is evident.

MIDDLE MIOCENE (KONKIAN OF THE EASTERN PARATETHYS) FORAMINIFERA ASEMMBLAGES FROM THE SOUTHERN UKRAINE

Yuliia V. Vernyhorova

National Academy of Sciences of Ukraine, Institute of Geological Sciences, O. Honchar str., 55 b, Kyiv, 01601 Ukraine

july.vern@gmail.com

The Konkian deposits are widespread in the Southern Ukraine in different lithofacies (Figure 1). Shallow-water deposits (3-25 m thickness) were accumulated in the Northern Black Sea Region and in the most parts of the Crimean Peninsula; deeper-water deposits (36-155 m thickness) were accumulated in the Kerch Peninsula, and in remote areas of the south-eastern territories of the Crimean Peninsula (e.g. ARKHANGUELSKY, 1930; MOLYAVKO, 1960; BARG & STEPANIAK, 2003).

Different types of limestones (upper parts of Hladkivka formation, Tarkhankut formation, Mekenziev strata) prevail in the western part of the Northern Black Sea Region and in the west and the south of the Crimean Peninsula; sands and sandstones (upper part of Novokakhovka formathion) are more abundant in the south-east of the Northern Black Sea Region and in the northen part and the centre of the Crimean Peninsula; laminated green-grey clays with varying sandy admixtures (upper part of Tymoshivka formation) occur in the north-eastern part of the Northern Black Sea Region (VERNYHOROVA 2015a, 2016). The Konkian deposits in these areas have hiatuses in sedimentation and these strata are not complete. They often don't correlate to the whole stratigraphic range of the Konkian of the Eastern Paratethys.

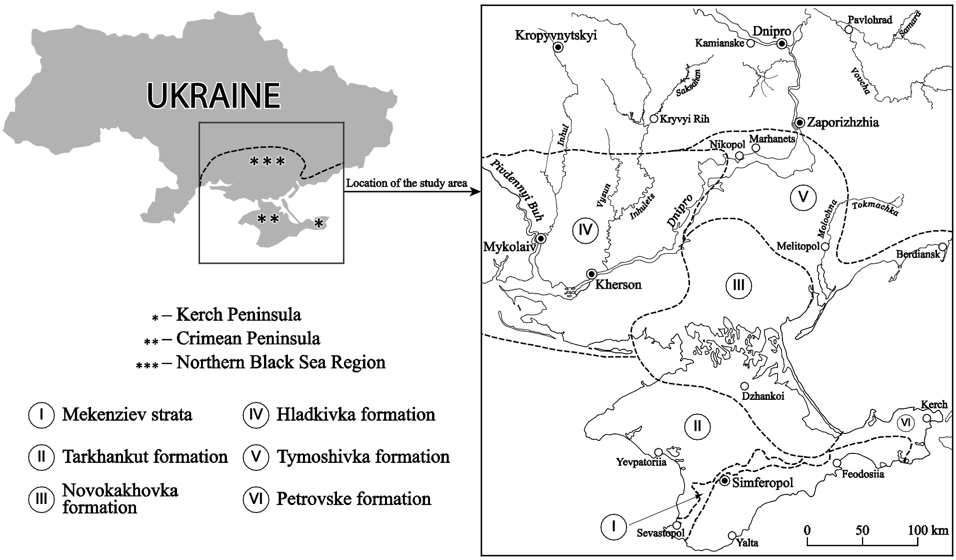

Figure 1. Distribution of Konkian (Upper Badenian) lithofacies on The Southern Ukraine (VERNYHOROVA, 2014-2016).

These shallow-water deposits have several foraminiferal assemblages. They are different in species composition. There are assemblages with dominance of normal-marine species (*Quinqueloculina pseudoangustissima* Krash., *Q. minakovae ukrainica* Didk., *Q. badenensis* d'Orb., *Varidentella reussi sartaganica* (Krash.), *Triloculina pyrula latodentata* (Didk.), *Nonionella ventragranossa* Krash., *Reussella spinulosa* (Reuss), *Borelis melo* (F. et M.), etc.) or euryhaline species (*Porosononion martkobi* (Bogd.), *P. subgranosus* (Egger) *Elphidium kudakoense* Bogd., *Ammonia* ex gr. *beccarii* (L.), etc.) or mixed assemblages which have equal proportions of normal-marine and euryhaline foraminifer species (e.g. DIDKOVSKIY, 1959; IVANOVA, 2012; VERNYHOROVA, 2015b).

The deeper-water Konkian facies are monotonous dark gray clays (Petrovske formation) on the Kerch Peninsula and in remote areas of the south-eastern territories of the Crimean Peninsula (e.g. ARKHANGUELSKY, 1930; VERNYHOROVA, 2014).

These deeper-water deposits include two foraminiferal assemblages. Normal-marine Konkian foraminifera (*Lagena*, *Bulimina*, *Buliminella*, *Uvigerina*, *Bolivina*, *Cassidulina*, *Discorbis*, *Virgulina* and *Quinqueloqulina*) were developed in the lower part of the section. Mainly euryhaline foraminifera (*Nonion*, *Ammonia*, *Elphidium*) with rare marine Konkian species and Early Sarmatian species (*Elphidium horridum* Bogd, *Nonion bogdanowichi* Volosh., etc.) are found in the upper part of the section (e.g. VERNYHOROVA, 2015). The distribution of the Konkian foraminifer assemblages in deeper-water deposits of the Kerch Peninsula is significantly different from those in the coeval shallow-water sediments of the Northern Black Sea Region and the Crimean Peninsula. Kerch foraminiferal assemblages are similar to those from the deep-sea Konkian sediments of the Taman Peninsula and the Western Ciscaucasia (e.g. POPOV & GOLOVINA, 2016).

The comparison of foraminiferal assemblages shows the fact that the Southern Ukraine has two types of paleobasins (shallow-water and deeper-water) with their own paleoecological characteristics and development during the Konkian time.

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BADENIAN OSTRACODS FROM POŽEŠKA GORA AND PAPUK MTS.

Marina Vesel Lukić[1,*] & Valentina Hajek Tadesse [2]

[1] Geološki zavod Slovenije, Oddelek za regionalno geologijo, Dimičeva ulica 14, 1000 Ljubljana, Slovenia
[2] Croatian Geological Survey, Department of Geology, Sachsova 2, 10000 Zagreb, Croatia

*corresponding author: marina.vesel-lukic@geo-zs.si

In our study, a rich and diverse fauna of ostracods is presented, separated from the marine Middle Miocene deposits from Požeška gora and Papuk Mts. The ostracod fauna was sampled from the Ljubin dol core, three outcrops situated at Banićevac, Lipovac and Crnka and nineteen different sampling locations from Mt. Požeška gora. Samples of Mt. Papuk belong to outcrops Gornji Vrhovci, Nježić and Radovanci, and thirty six different sampling locations.

Detected marine ostracods belong to the suborder of Platycopa and Podocopa, more precisely, to the families Cytherellidae, Bairdiidae, Cyprididae, and Cytheridae.

In addition to the presence of zonal markers for the Ostracod Biozone for the Badenian (JIŘÍČEK, 1983; JIŘÍČEK & ŘÍHA, 1991), we attempted to define the attribution of samples to a particular zone, out of the two Badenian ostracod zones recognized so far: the Early Badenian biozone NO–7 *Acanthocythereis hystrix – Bythocypris lucida* and the Middle Badenian biozone NO-8 *Eocytheropteron inflatum – Olimfalunia spinulosa*.

The occurrence of regional ostracod marker *Bythocypris lucida* and *Acanthocythereis hystrix* in a observed samples confirms the Early Badenian age of these deposits. Species *Bythocypris lucida* is common and more abundant, while the *Acanthocythereis hystrix* was found in a small amount in the entire research area. In addition to the regional ostracod zonal markers in the study area we defined two local Early Badenian ostracod markers: *Cytherella postdenticulata* and *Incongruellina keiji.*

Generally, ostracod assemblages of Early Badenian samples have a deep-water character. A higher quantity of deeper water species like *Bythocypris lucida*, *Henryhowella asperrima*, *Acanthocythereis hystrix*, *Krithe citae*, *Krithe* sp., *Parakrithe dactilomorpha*, *Butonia dertonensis*, *Paracypris* sp., *Macrocypris* sp., *Cytherella postdenticulata* and *Cytherella compressa* together with different shallow marine species of genera *Aurila, Xestoleberis, Bairdoppilata* and *Loxoconcha* were determined.

Discovery of "new-entry" Tethys species *Ruggieria* ex. gr. *carinata*, *Ruggieria* sp., *Saida* sp. and Indo-Pacific species *Paijenborchella iocosa* indicate the establishment of the Tethys-Paratethys-?Indo Pacific connections.

The samples which belong to the Middle Badenian biozone NO-8 were determined by a number of findings of the marker species *Olimfalunia spinulosa*. The second marker of this zone *Eocytheropteron inflatum* was not found, while in previous research (HAJEK-TADESSE & PRTOLJAN, 2011) these species have been found in Middle Badenian sediments of the Pokupsko area.

Ostracod fauna of the Middle Badenian samples can be defined as a shallow water marine fauna. The samples are dominated by the *Aurila haueri*, *A. trigonella, A. angulata*, *A. cicatricosa*, *Olimfalunia spinulosa, O. plicatula*, *Bairdoppilata* sp., *Loxoconcha hastata* and *L. punctatella*. Less abundant are deeper water species like *Henryhowella asperrima*, *Pterygocythereis calcarata*, *Krithe cf. citae* and *Krithe* cf. *monosterancensis* which indicate a still good communication with the open sea.

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NEW CHRONO-BIOSTRATIGRAPHIC INTERPRETATIONS BASED ON CALCAREOUS NANNOFOSSILS OF LOWER MIOCENE MARINE DEPOSITS LOCATED BETWEEN BURDUR AND ISPARTA (SW TURKEY)

Gülin Yavuzlar* & Enis Kemal Sagular

Suleyman Demirel University, Faculty of Engineering, Department of Geological Engineering

*corresponding author: gulinyavuzlar@gmail.com

This study focused on the new biostratigraphic results and chronostratigraphic interpretations of Tertiary nannofossils in the marine sedimentary rocks around Gökçebağ (Burdur) and Yakaören (Isparta) villages, located in southwestern Turkey. The study area exposes several autochthonous sedimentary rock sequences which are mainly dominated by volcano-sedimentary and sedimentary successions overlying an allochthonous basement including ophiolithic melange and deep marine sedimentary units. Particularly, two discontinuous successions which were described as Early Tertiary age in the previous studies were dealed. One of them is the marine carbonate and clastics deposited in Paleocene-Lutetian. The second is the marine shelf clastics of which their depositional time is assumed as Lutetian or ranging from Lutetian to Burdigalian. Two formations were stratigraphically redefined and reinterpreted in this study based on new nannofossil records determined by discriminating with respest to origin. Synsedimentary, removed and/ or reworked nannofossil species were distinguished and classified depending on their original relationships in the fine-grained rocks of the same succession.

Four nannofossil interval zone were defined within biostratigraphic studies: (1) NP17 *Discoaster saipanensis* biozone (belongs to the Isparta Formation in a local area) including Lutetian nannofossil assemblage, i.e. *P. inversus, S. orphanknollensis; S. spiniger, C. marismontium* and *S. spiniger*; (2) NN1 *Triquetrorhabdulus caritanus* biozone of Aquitanian by the presence of *C. floridanus, C. abisectus, T. carinatus* (belongs to the Güneyce Formation); (3) NN2 *Discoaster druggii* biozone of Aquitanian–Burdigalian age, existence of *D. druggii, T. challengeri* (Güneyce Formation); and (4) NN3 *Sphenolithus belemnos* biozone indicating Burdigalian age (Güneyce Formation) with the nannofossil assemblage including *C. miopelagicus, S. compactus, S. belemnos, S. disbelemnos, S. conicus, R. haqii, S. moriformis, T. milowii*.

According to the new nannofossil findings, Tertiary marine sequences between Isparta and Burdur were reinterpreted and two marine sedimentary succession, Isparta Formation (Lutetian) and Güneyce Formation (Early Miocene) were defined instead of the formations mainly referred to the Early Tertiary sedimentation. Eventually, geological map of the studied area was verified by means of field observations and remote-sensing studies in addition to new biostratigraphic data.

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