The First find of otoliths of the Miocene from Eastern Serbia (Dacian Basin)

Katarina Bradić-Milinović, Meri Ganić, Damjan Dimitrov

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Preface

Under auspices of the Regional Committee on Mediterranean Neogene Stratigraphy (RCMNS) and International Commission on the History of Geological Sciences (INHIGEO), Serbian Geological Society and the Organizing Committee had great pleasure to organize the scientific conference entitled "100 years of the Paratethys (Laskarev, 1924) – Conceptual History and Modern Challenges" from September 30th to October 1st, 2024 in Belgrade.

This event was initiated by the Commission of Neogene and Quaternary and History of Geology Division of the Serbian Geological Society during its last Annual Assembly (2023). That proposal was accepted with great pleasure, and soon the Organizing Committee was formed. To our great satisfaction, we were shortly joined by other organizations that recognized the importance of celebrating the great jubilee. In the first place, the Serbian Academy of Sciences and Arts accepted that the scientific part of the meeting with all the lectures be held in the Main Hall of the Academy, to increase the memory of their former member and Academician V. Laskarev. The Faculty of Mining and Geology in Belgrade and the Museum of Natural History immediately agreed to help the organization, considering that V. Laskarev was a long-time professor of geology and paleontology and the honorary curator of the Museum. Besides, student volunteers expressed their willingness to participate and help the organization of this great event at the very beginning.

Of course, thanks also go to all other people and organizations who helped in any way to mark this great jubilee for the geology of our country in the best way. Considering the difficult economic and political conditions in a part of Eastern Europe, it remains regrettable that a lot of colleagues from that area could not participate directly.

The term Paratethys is a universal term used by geologists all over the world and we are grateful that we had the privilege and honor to host our colleagues from different countries and show them something of our Paratethys geological heritage that we all use and promote today.

The Organizing Committee tried their best to make all the participants feel welcome in Belgrade, and we deeply believe that they will take such feelings back to their homes.

The Editors

A B S T R A C T S*

INVITED LECTURES

**Alphabetically by surname of the first author*

"100 years of the Paratethys (Laskarev, 1924) – Conceptual History and Modern Challenges"
September 30th - October 1st, 2024

The Central Paratethys Sea – Rise and demise of a Miocene European marine biodiversity hot-spot

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Hundreds of papers have been devoted to the taxonomic description and analysis of Paratethyan fossils, and its biota is reasonably well known. However, surprisingly few attempts have been made to analyze the distribution of selected taxonomic groups on a pan-Paratethyan scale. Former studies were literature-based data collections, amalgamating a multitude of different taxonomic traditions, incongruent species concepts and a generally broadly scattered quality of research. These issues render many taxonomic datasets internally incomparable and can severely bias reconstructions of species richness, biogeographic relationships, and evolutionary trajectories. To overcome this problem and to minimize the impact of taxonomic artefacts we specifically use a dataset that was developed by critical taxonomic revisions performed mainly by M.H. and B.L. during the last 15 years. Here, we present a georeferenced dataset of 859 gastropod species to trace changes in diversity and distribution through the Early and Middle Miocene.

We observe a remarkable increase of diversity during the Langhian, coinciding with the Miocene Climate Optimum (MCO). During a subtropical to tropical regime, this sea harbored an extraordinary biotic diversity. The tectonic reorganization around the Early/Middle Miocene boundary resulted in the formation of an archipelago-like landscape and favorable conditions of the MCO allowed the establishment of coral reefs. Both factors increased habitat heterogeneity, which boosted species richness. The subsequent cooling during the Middle Miocene Climate Transition (MMCT) caused a drastic decline in biodiversity. Among the most severely hit groups were corallivorous gastropods, reflecting the loss of coral reefs. Deep water faunas experienced a dramatic loss of the species, and the low sea level led to a fragmentation of the fauna and regional endemics evolved.

"100 years of the Paratethys (Laskarev, 1924) – Conceptual History and Modern Challenges"
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Causes and consequences of Paratethys sea retreat

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Paratethys was a large continental sea that formed in Central Eurasia because of plate tectonic closure of the Tethys Ocean and formation of the Alpine-Himalaya Mountain belt. The Paratethys Sea initially extended from France in the west to western Asia in the east. The disappearance of this large water mass (Black Sea and Caspian Sea are the only remnants) had much impact on Central Eurasian climate. Paratethys' semi-isolated setting gave rise to remarkable palaeoenvironmental changes, and its ancient sedimentary deposits provide excellent geological archives for reconstructing past climate systems. The presence and disappearance of this large epicontinental sea also had a dominant role on marine and brackish fauna evolution and on the migration patterns of mammals from Asia to Europe.

Here, updates on Paratethys stratigraphy will be presented, describing the main progress in dating the sea retreat over the last 20 years with revised paleogeographic maps of the region. Focus will be on the large-scale evolution of this lost sea, including its birth (widespread anoxia), mid-life crisis (widespread hypersalinity) and its demise (widespread freshening). In addition, the forcing mechanisms of sea retreat, which include geodynamics, sedimentological infill and global sea level, will be shown. Finally, the relevance of Paratethys retreat will be discussed in the light of interbasinal connectivity and comparison with the modern Black Sea analogue.

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The Early Miocene of the Western Paratethys: Time of major environmental changes and biotic turnovers

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The Western Paratethys, which developed during the Late Eocene/Early Oligocene, spans from Haute Savoy in France through Switzerland and Southern Germany, roughly aligning with the longitude of Munich; the eastwards adjacent area is already part of the Central Paratethys. The separation between Western and Central Paratethys arises from disparate environmental conditions during the Late Oligocene and Early Miocene, when the Western Paratethys was drained by a large river system (Lower Freshwater Molasse), whereas the Central Paratethys retained marine conditions (Lower Marine Molasse). Oligocene-Miocene sediment thickness varies, ranging from a few tens of meters in distal areas to over 4000 meters in proximal regions near the Alps. The sediments mainly derive from the Alpine region and to a reduced extent from sources to the North.

Research on the sedimentary record of the Western Paratethys, however, poses significant challenges. Lithofacies can change considerably over short geographic distances, different regions may feature highly unique or endemic (micro)faunas, and volcanic ashes or bentonites suitable for radiometric dating are scarce. Consequently, establishing chronostratigraphic correlations within the Western Paratethys, across Western, Central and Eastern Paratethys, and between the Paratethys and the Mediterranean has been a matter of debate since a long time. Nevertheless, comprehensive interdisciplinary studies, integrating (micro)palaeontology, biostratigraphy, magnetostratigraphy, Ar/Ar dating, and sequence stratigraphy, have markedly improved correlations between regional Paratethys stages and the international stages of the Global Time Scale. This advancement enhances our understanding of how global climate change and/or Alpine orogenesis influenced observable paleoenvironmental and paleogeographic shifts in the Western Paratethys.

My presentation will focus on the environmental and biotic transitions during the Early-Middle Miocene (Ottnangian–Karpatian–Badenian) in the Western Paratethys and Molasse Basin of Switzerland and Southern Germany, respectively. This period encompasses the retreat of the sea from the Western Paratethys, termed the 'Rzehakia event', which is also observed in the Central Paratethys. It includes the emergence of highly diverse brackish and lacustrine settings, often characterized by abundant occurrences of the bivalve *Rzehakia*, alongside biotic turnovers and extinction among mammal, fish, and gastropod species. I will present our latest results on the chronostratigraphic age of the 'Rzehakia event' and explore the evidence that suggests a potential link to global climate change.

SESSION 1

All the aspects of Paratethys geology

Architectural asymmetry of Neogene sediments in the area of Fruška Gora Mt. (Serbia): northern vs. southern depositional area

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The Fruška Gora Mountain has been a target of fundamental and applied geological exploration for almost two centuries, with Vrdnik coal basin being one of the topics sparking initial interest in the area. Building on this foundation, some new concepts are introduced into the local geology. Fruška Gora is an anticlinal-type inselberg within the Pannonian Basin, with its evolution influenced by the Europe-Adria convergence, and later Miocene extensional processes. Its younger tectonic history is represented by Pliocene-Quaternary basin inversion. The structure of Fruška Gora is dominated by the neotectonic Srem Dislocation along its axis, which thrusted the ophiolitic complex over Cretaceous-Paleogene sediments and separates southern and northern Paratethyan depositional areas.

In the southern area, the most striking feature is the thick Lower Miocene *rift initiation* lacustrine-fluvial coal-bearing Vrdnik Formation. It is overlain by Badenian conglomerates and subreefal limestones, a thin Sarmatian littoral-sublittoral unit, with marly sediments continuing to be deposited in the Pannonian in a brackish-lacustrine hemipelagic setting. The depression was finally filled by Pannonian delta slope and delta front siliciclastics, and transitional Pannonian-Pliocene fluvial coarse terrigenous sediment.

The northern area shows a similar pattern. Lower Miocene deposits have more areal extent, but less thickness than the Vrdnik Formation, and were biostratigraphically correlated with it. Badenian sediments are more extensive and facially diverse, comprising said subreefal limestones, but also lagoonal and offshore clays and marls, and littoral sands. Sarmatian has comparable properties as in the south, showing a continually deepening environment, starting with littoral sands, and then progressing into sublittoral limestones and marls. Caspibrackish Pannonian is markedly better exposed, continuing from Sarmatian to first display thin sublittoral marly limestone, and then a 200m thick hemipelagic calcareous marl unit of the Beočin Formation. Younger Pannonian littoral-estuarine sands cover them, and some of the area remains flooded into the Pliocene as a part of the shallow freshwater Paludina/Slavonia Lake, finally filling up by rivers in later Pliocene and earlier Pleistocene.

Tectonic trajectories are fairly steady throughout the basin cycles but diverging slightly during the Badenian and Pannonian. The northern area has Pannonian basinal elements much better exposed, while lacking the delta slope element and progressing directly into shoreface/delta front sands. Average thickness plots, however, shows significant divergence, but since the lower boundary of the Pannonian is poorly constrained in the southern part, it remains an open question.

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The southward expansion of Central Paratethys Sea (Central Europe): inferences from Prnjavor, Tuzla and Lopare basins

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The Central Paratethys Sea developed across the junction of the Alps, Dinarides and Carpathians during Oligocene to Miocene times. During the Middle Miocene, the sea spread southeastwards, an event commonly known as the Badenian flooding. However, this marine expansion is poorly constrained in space and time. The present work uses radiometric dating to construct the Middle Miocene absolute chronology of the marine expansion along the southern margin of the Central Paratethys flanking the NE Dinarides (NE Bosnia and Herzegovina). Finally, the governing mechanisms are discussed. The new U-Pb zircon ages were acquired by LA-ICP-MS from volcanic ash layers sampled in the Tuzla, Lopare and Prnjavor basins (Bosnia and Herzegovina). Our new data constrains the onset of marine flooding along the southern marginal basins of the Central Paratethys at ~14.2 Ma. Considering previously published and new ages it is suggested that marine expansion of the Central Paratethys along the flanks of the NE Dinarides lasted about 3-4 Myrs. The extension affecting the Dinarides following the opening in the neighboring Pannonian Basin promoted subsidence and S/SE-directed successive propagation of a marine environment.

Lake Pannon dinoflagellate cysts: why are they useful despite all the challenges?

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Dinoflagellate cysts have been extensively used to develop regional biostratigraphical schemes for the Late Miocene deposits of Lake Pannon. Moreover, the isolated evolution and of the lake initiated a remarkable endemic evolution among dinoflagellate cysts characterized by large morphological plasticity. Key members are primarily related to the marine genera *Spiniferites*, *Achomosphaera*, *Impagidinium* and *Pyxidinopsis*. The genus *Pontiadinium* and several species e.g., *Thalassiphora balcanica, Galeacysta etrusca* and possibly *Spiniferites cruciformis* originated from the lake and were later also recorded in the Ponto-Caspian realm, hence understanding their taxonomy, origin and ecology has widespread interregional implications. Despite the plethora of data from all parts of the Pannonian Basin. their taxonomy and consequently their biostratigraphical and paleoenvironmental implications are not well understood. Although the taxa are separated as different species for the purpose of biostratigraphy, they likely belong to few motile cell genera that produced different cyst as a response to changing environmental conditions in Lake Pannon and were genetically closely related.

From new materials from Hungary and Croatia we demonstrate how this ecophenotypic variation led to the development of new species. We revise the taxonomy of species originally described as *Spiniferites*, albeit their morphology makes them more comparable *Achomosphaera*. We present possible evidence for an earlier appearance of cruciform morphologies in *Spiniferites,* and a cyst type similar to *Galeacysta* occurring *ca.* 2 million years earlier than previously thought. Integration of the biostratigraphical data with magnetostratigraphy or authigenic Be dating has helped revise the dinoflagellate cyst-zonation.

This research was funded by the WEGETA internal research project at the Croatian geological survey, funded by the National Recovery and Resilience Plan 2021–2026 of the European Union – NextGenerationEU and by the National Research, Development and Innovation Office of Hungary (NKFIH K 143787 grant).

Upper Miocene freshwater succession of Posavo-Tamnava basin (Internal Dinarides, NW Serbia)

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Posavo-Tamnava peri-Pannonian basin of Serbian Internal Dinarides started its evolution following the Oligo-Miocene orogenic collapse and extension in the area. The two-vergence extension activated large-scale normal faults (Marović et al., 2002) in NW-SE direction parallel to orogen and in NE-SW direction perpendicular to it, in genetic relation with sedimentation onset during Lower-Middle Miocene. During Miocene and Pliocene eastern and central parts of basin are filled with freshwater, marine, brackish, and lacustrine sediments (Rundić, 2000), while in the southwest and south circumferential younger Miocene succession referred to as "lacustrine" is formed (Mojsilović et al., 1977).

Erosional remnants of this unit at Vlašić Mt. contain in basal levels palynological association: *Subtriporopollenites simplex*, *Pollenites* sp., *Salixpollenites* sp., *Myricypites* sp., *Laevigatosporites haardti*, *Inaperturopollenites dubius*, *I. instructus*, *Triporopollenites coryloides*, *Alnipollenites verus*, *Carpinipollenites* sp., *Tricolpopollenites* sp. *Umbeliferoipollenites* sp. that constrain the onset of sedimentation to?Upper Miocene (Đajić, 2022).

The middle levels of succession are represented with sands and sandy gravels, in vertical and lateral interchange with clays. These are thinly bedded trough-cross to horizontally laminated kaolinitic-illite clays, interbedded with infrequent layers of fossil wood (coal) fragments, deposited along the small-angle paleoslope further in basin. They are followed by two-unit (gravel-shale) sequences with gradation and trough-cross stratification, arranged in cyclic pattern. The upper part of succession is represented with large-scale trough-cross stratified fine- to coarse-grained sands (occasionally with low-angle trough, rarely tabular cross-stratification) with slump soft sediment (SSD), erosional channels, irregular Fe- and Mn-pigmentation and infrequent horizontal lamination (shale interbeds).

The characteristics of deposits studied in a few local sections point to delta environment dominated by distributary channels in the upper levels, as a part of complex lacustrine area. The mineral association of quartz, feldspar, mica, carbonate, and other rock fragments (including low-grade metamorphic), as well as tourmaline, rutile and zircon, apatite and metallic minerals and coated grains point to complex provenance where magmatic complex, various metamorphic and sedimentary rocks, often transported by fluvial agents, significantly contributed.

Overview of Middle Miocene otoliths from Serbia (Central Paratethys)

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Here we presented rich assemblages of otoliths from the Lower Badenian to Sarmatian age from Central to Western Serbia. Otoliths were collected from several localities: five from the Badenian (Koceljeva, Kamenovo, Slanci, Barajevo and Rakovica stream) and five from the Sarmatian (Tabanovac, Malo Laole, Petrovac, Leskovac and Barajevo) age.

We identified in total thirty-nine different species: Clupeidae: *Maeotichthys* sp.; Synodontidae: *Saurida* sp.; Cyprinodontidae: *Aphanolebias sarmaticus*; Myctophidae: *Diaphus acutirostrum, Diaphus austriacus, Diaphus extremus, Diaphus kokeni*; Bregmacerotidae: *Bregmaceros albyi*; Gadiae: *Gadiculus argenteus, Palimphemus* aff. *minusculoides*; Atherinidae: *Atherina* sp.; Gobiidae: *Aphia djafarovae, Aphia macrophthalma, Eleogobius prochazkai, Gobius mustus, Gobius reichenbacherae, Gobius supraspectabilis, Lesueurigobius vicinalis*, *Lesueurigibius* sp.1, *Moldavigobius suavis, Ponticola wiesenensis, Proneogobius* aff. *pullus, Proterorhinus manfredi, Proterorhinus vasilievae, Vanderhorstia prochazkai, Buenia rudolticensis, Buenia* sp.1, *Deltentosteus telleri, Economidichthys triangularis, Economidichthys* sp.1, *Hellenigobius bunyatovi, Hesperichthys hesperis, Pomatoschistus bunyatovi, Pomatoschistus elegans*; Bothidae: *Arnoglossus? tenuis, Arnoglossus* sp.; Blenniidae: *Blennius? martinii*; Triglidae: *Persitedion* sp. juv. and *Scorpenid* indet.

The represented fossil fauna of Miocene otoliths from the territory of Serbia correspond to Miocene evolution of Central Paratethys. Fossil assemblages of otoliths from Lower Badenian from Serbia are represented with fishes typical for an open marine environment with domination of mesopelagic families Myctophidae and Bregmacerotidae. These mesopelagic families are characterized by other time equivalent locations in the Central Paratethys. The otoliths from the Upper Badenian and Sarmatian are dominated by the family Gobiidae. However, the Gobiidae represent the most species-rich group overall. This change in faunal composition indicates an environmental change from open marine to restricted marine and to shallow water of sublittoral environments.

The First find of otoliths of the Miocene from Eastern Serbia (Dacian Basin)

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Here we present a first data of otoliths assemblage of the Miocene sediments from Eastern Serbia, (Dacian Basin). The Miocene sediments spread in eastern Serbia, along the border with Romania and Bulgaria, were formed along the western rim of the Dacian Basin. Otoliths were examined from: marine sediments of Badenian, brackish sediments of Sarmatian (Volhynian, Bessarabian and Khersonian), and marine-brackish sediments of Maeotian stage. Studied material with rich assemblages of otoliths were collected from several localities of Negotinska Krajina area: Veliki uzvor (Badenian), Tamnič (Volhynian), Kovilovo (Bessarabian), Bukovo stream (Khersonian) and Mihajlovac (Maeotian).

The represented fossil fauna of Miocene otoliths from the territory of Eastern Serbia correspond to Miocene evolution of Eastern Paratethys. Fossil assemblages of otoliths from Badenian sediments represented with fishes typical for an open marine environment with domination of family Gobiidae. The otoliths associated with Sarmatian are dominated by the family Gobiidae, represented with Ponto-Caspian forms. Sarmatian sediments are characterized by the presence of families of Clupeidae and Gadidae, but less numerous than Gobiidae otoliths. The dominance of Gadidae and Gobiidae indicates an inner-neritic to coastal environment with high productivity. Otoliths specimens from Maeotian stages are determined only as representatives of family Gobiidae. Otoliths of the family Gobiidae are preserved in all segments of Miocene sediments (from Badenian to Maeotian) in the study area. Their presence in all the study of Miocene sediments tells us about their ability to adapt to different environmental conditions. This group has the ability to rapidly adapt to different changes in the environment. Otoliths are particularly useful because they can provide important information on palaeoenvironments, palaeogeography and evolution.

Crushed and fragmented snake remains from the lacustrine sediments of Vračević (Middle Miocene, Serbia) - identification and reconstruction possibility

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During fossilization snake vertebrae easily disarticulated and transported. In fossil associations they are mostly found isolated with dimensions often do not exceed 5 mm. They are out of several hundred vertebrae per individual, only a few vertebrae are found in the fossil state. Throughout transportation the vertebrae are damaged, specific taxonomic characters become less noticeable and identification difficult. The fossil association of snakes from the Middle Miocene site of Vračević includes dozens of isolated vertebrae, more or less damaged. In the lacustrine sediment, the remains of snakes came from the immediate surroundings. In the first identifications (2005-2011), 27 vertebrae were recognized as representatives of the families Viperidae (*Vipera* sp.) and Colubridae (*Elaphe* sp., *Natrix* sp., and *Coluber* sp.) and one representative of Scolecophidia. In subsequent years, vertebrae with partially preserved characters from the family Erycidae were isolated. Also were recognized the vertebrae most similar to the genera *Neonatrix* sp. and *Texasophis* sp. from the family Colubridae, as well as the species *Coluber* cf. *dolnicensis*. Some vertebrae with viperid characteristics are most similar to the species *Vipera antiqua*.

In addition to damage during fossilization, aggravating circumstances in the identification of these remains is the great intra-columnar variability. Also, the lack of remains of the head skeleton makes precise identification difficult. Regardless of all this, any information that can be extracted from the remains of snakes in combination with other members of fossil associations contributes to a better understanding of paleoenvironments.

New data on the distribution of the genus *Apscheronia* in the Euxinian basin

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In the Late Miocene, the Eastern Paratethys had split into independent Euxinian and Caspian basins. The origin of the specific Late Pliocene – Early Pleistocene Akchagylian and Apsheronian fauna of molluscs are still unclear. Among enigmatic forms is the smooth shelled bivalves *Apscheronia* (Cardiidae). Several ribbed forms, originally allocated to this genus, were later placed into the genus *Parapscheronia*. There were different opinions that these ribbed forms originated from Sarmatian or Akchagylian species. The smooth *A. propinqua* could have originated from *Parapscheronia,* different Akchagylian Cardiidae, or from the lower Apsheronian *Apscheronia pygmaea* and *A. propinqua* var. *mica* (possibly being synonymous).

According to another viewpoint, expressed by Vladimir Bogachev, the Apsheronian fauna migrated from the Azov-Black Sea region. Co-occurence of *A. propinqua* and *Bogatschevia sturi* in the borehole near Yeysk became the first evidence of the presence of the Apsheronian fauna in the Azov Sea basin. In 2016-2017, much to the south, on the northern coast of the Taman Peninsula in the Tizdar/Kermek locality, shells of *A. propinqua* were found together with *Margaritifera arca*, *Bogatschevia sturi*, *Bogatschevia* aff. *scutum,* and small mammals *Allophaiomys deucalion* and *Lagurodon arankae*. The small mammal fauna belongs to the regional biozone MQR10-11. In combination with a normal polarity interval at the top of the section (interpreted as Olduvai Subchron), the Tizdar section is correlated with the terminal Gelasian (2,1–1.8 Ma).

The time range of the Akchagylian basin is debatable. According to one of the models, the boundary between Akchagylian and Apsheronian basins does not correspond to the upper part of the Olduvai Subchron (1.8 Ma) but is confined to the Reunion Subchron (2.1 Ma). If followed, the appearance of the type subspecies *A. propinqua* in the Black Sea and Caspian regions occurs at an almost synchronous level below the Olduvai Subchron.

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The crystallization temperature of halite in the Badenian saline basins in the Carpathian region based on microthermometric analyses of fluid inclusions

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The Paratethys was a system of interconnected epicontinental seas linked with the Mediterranean and periodically with the Atlantic and Indian Oceans. That chain of basins existed in various configurations from the early Oligocene to the late Middle Miocene. Episodically, due to complex tectonic and/or glacio-eustatic processes, the marine gateways to open oceans were closed, and the hydrological exchange between different basins was restricted. Consequently, large hypersaline waters became the sources of regional-scale saline formations, developed from the Burdigalian to the Serravallian in the Carpathian area, the Red Sea, and the Middle East.

The Badenian Salinity Crisis (B.S.C.) during the Middle Miocene (around 13.8 to 13.4 million years ago) triggered widespread salt deposition, yielding Badenian salts across modern-day Poland, Ukraine, Romania, Slovakia, Hungary, and Bosnia and Herzegovina. Similar lithology and stratigraphic positions of these deposits suggest homogeneous paleoclimatic conditions in Central Paratethys. The fluid inclusions study provides valuable information on temperature, pressure, and fluid composition correlated with various geologic processes. Our research focuses on primary fluid inclusions within halite to determine halite crystallization temperature and paleotemperature of brine, which is crucial for understanding paleoclimate during salt deposition. We conducted 435 temperature measurements of homogenization in single-phase fluid inclusions from various Carpathian salt basins. Samples were carefully selected from Wieliczka, Hrynivka, Zbudza, Slanic-Prahova, Okna Dej, and Solotvyno.

Our research confirmed that paleotemperatures were reconstructed effectively using preliminary cooling of halite samples containing single-phase fluid inclusions, followed by subsequent homogenization of inclusions. In each studied sample, homogenization of inclusions occurred in a narrow temperature range. For example, the spread of homogenization temperatures did not exceed 9°C in the case of chevron halite inclusions. When a sufficiently large number of determinations were available, the accurate mineral formation temperatures were determined based on the maximum value of the homogenization temperature.

The range of homogenization temperatures observed, from 13.0°C to 36.0 °C, provides a comprehensive understanding of the crystallization temperatures in these salt basins. It was determined that the chevron bottom halite of the Badenian salt-bearing basins of the Carpathian region crystallized from cooled supersaturated near-surface brines. Consequently, the bottom brines' temperature was consistently lower than that of the surface brines. On the surface, the temperature ranged from 34.0 to 36.0°C, and at the bottom of the basin, from 19.5 to 22.0°C and 24.0 to 26.0°C. This temperature distribution correlates with modern deep sea water column temperatures, akin to the Dead Sea.

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Overview of Neogene sedimentary succession in Slovenian part of the Pannonian Basin System

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Northeastern and eastern Slovenia is located in the Southeastern Alpine foreland, which is significantly influenced by the collision of the Adriatic and European tectonic plates. This has resulted in a highly complex geological structure, characterised by diverse depositional environments shaped by both local tectonic activity and broader regional geodynamic processes. Significant Neogene sediments are preserved in three key areas, the first north of the main structure of the Periadriatic Fault (PAF), the second south of the PAF and the third south of the Sava Folds. All three areas developed were influenced by global eustatic cycles and experienced phases of extensional tectonics, resulting in the formation of extensional basins filled with sedimentary sequences. Deposition of the oldest Neogene sediments continued from the Oligocene, are Egerian and Eggenburgian and are preserved south of the PAF. The Otnangian and Karpatian successions are preserved north of the PAF in separate basins, where the sedimentation has been related to the development of the Mura-Zala and Styrian basins. Nannofossil assemblages indicate the connection between the Central Paratethys (north of the PAF) and the Mediterranean in the Karpatian (TB 2.2) and during the first (TB 2.3) and second (TB 2.4) Badenian transgressions. While early Badenian sedimentation took place north and south of the PAF, the Krško area was flooded in the late Badenian. The sedimentary environment changed from terrestrial, transitional to shallow marine environments in all three areas with deposition of mostly coarse to fine-grained sediments, lithothamnium limestone and small coral patch-reefs in some places. The exception was the Mura-Zala Basin, where extensional tectonics established a deep-water environment. The Sarmatian is characterised by a marine to brackish environment with reduced salinity with deposition of fine-grained sediments (silt, marl). The Pannonian sedimentation is characterised by the formation of deltaic systems. The largest was established in the Mura-Zala Basin, and one in the Krško area. In both cases the delta slope, delta front and delta plain sediments are present, and on the top alluvial plain with swamps and lakes. The Plio-Quaternary period is characterised by significant climatic changes, marked by glacial and interglacial phases. In that period formation of fluvial terraces occurred, and the present-day drainage system was established.

From the Paratethys Sea to the brackish Lake Pannon; the Middle and Upper Miocene deposits of the North Croatian Basin, Voćin locality

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On the northern slopes of the Mt. Papuk, south of Voćin in eastern Croatia, a continuous sequence of Miocene deposits with a thickness of about twenty meters is exposed at the surface. Based on field observations, mineralogical-petrographic analyzes and fossil content, five facies were distinguished: marl (F1), biocalcarenite/biocalcirudite (F2), clay (F3), sand (F4) and platy limestone (F5).

The lithological features and fossil content indicate that massive marls of the facies F1 and biocalcarenites/bicalcirudites of the facies F2 from the lower part of the section belong to a shallow marine environment of the Late Badenian. A 30 cm thick layer of clay consisting of smectite (F3), which lies within the F1 facies, probably formed by the alteration of pyroclastic material, indicates weak volcanism at the end of the Badenian. Horizontally laminated marls of the facies F1 from the central part of the section were continuously deposited above the massive marls of the same facies. Their microfossil assemblage indicates a Sarmatian age. Massive marls of the facies F1 and platy limestones of the F5 from the upper part of the section contain brackish ostracods which, together with nannoplankton assemblage and molluscs, suggest a Late Miocene age. Very thin sand (F4) layers in the middle and upper part of the section are mineralogically and structurally immature. Their composition indicates a local origin of siliciclastic detritus from the magmatic and metamorphic basement of the Pannonian Basin, which was exposed in the central part of the Papuk Mountains.

The Voćin section in the eastern part of the North Croatian Basin, which is only eighteen meters thick, recorded a decisive environmental change from the shallow marine environment of the Central Paratethys of the Middle Miocene to the shallow brackish environment of the Lake Pannon at the beginning of the Late Miocene.

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From disputed Sarmatian *sensu lato* Stage to independent Volhynian, Bessarabian and Khersonian Stages: progress in dating, definition and biozonation.

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The 'Sarmatian Stage' is a significant regional stratigraphic unit of the Paratethys, covering the largest portion of the Serravallian-Tortonian history. This period marks the hydrological isolation of the united Central and Eastern Paratethys from the global ocean, transforming the West Eurasian interior into the largest endorheic lake. This remarkable hydrological change resulted in several extreme water-level fluctuations and had a massive impact on the biotic record – from its impressive radiation to a near-total extinction. The term and definition of "Sarmatian" was first introduced for the Central Paratethys by Suess in 1866 in agreement with Barbot de Marny, who later used this term for the Eastern branch. Later, when it became clear that in both basins, Sarmatian has different stratigraphic volumes, the III Symposium of the Paratethys Working Group in frame of the RCMNS (1970) accepted a temporal solution: The Sarmatian was split into Sarmatian *sensu stricto* for the Central Paratethys (12.65 – 11.6 Ma) and Sarmatian *sensu lato* for the Eastern one (12.65 – 7.65 Ma). Since then, no attempts have been made to resolve the age-old stratigraphic dilemma. Much of the lack of progress arises from the yet missing comprehensive biostratigraphic and age constraints, especially, between the Sarmatian s.l. substages – Volhynian, Bessarabian and Khersonian.

Here, we present the recent and ongoing progress in dating, definition and biozonation of the Volhynian, Bessarabian and Khersonian (sub)stages along the three key-outcrops: Karagiye (Caspian Basin, Kazakhstan), Nadarbazevi (Caucasian Foreland, Georgia) and Jgali (Euxinian Basin, Georgia). Our integrated magneto-biostratigraphic age constraints suggest the following ages: Volhynian–Bessarabian – 12.0 Ma, Bessarabian–Khersonian – 9.9 Ma. Moreover, our comprehensive and well-dated reconstruction of the biotic record (molluscs, ostracods, foraminifers and calcareous nannoplankton) shows that Volhynian, Bessarabian and Khersonian have very distinct biotic characteristics that allow us to propose them as independent stages. Moreover, the new age constraints allow us to better understand the drivers of Sarmatian s.l. hydrological and biotic perturbations in the Eastern Paratethys and will further largely contribute to paleoclimatic and paleobiogeographic studies on the vast Eurasian Interior.

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100 years after Laskarev: chronostratigraphic correlations of the upper Neogene in the Paratethys domain

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In his 100-year-old, celebrated paper ("Sur les équivalents du Sarmatien supérieur en Serbie"), Laskarev discussed three topics. First, he coined the name "Paratethys" for the Neogene inland sea of central and southeastern Europe, and shortly described its paleogeographical and environmental evolution. Second, he recapitulated and confirmed the upper Neogene chronostratigraphic correlation between the Pannonian Basin and the Eastern Paratethys suggested earlier by Andrusov. Finally, he described his field observations made in surface outcrops of Sarmatian and Pannonian deposits around Belgrade.

His major points in correlation were that 1) the uniform paleontological record of the lower Sarmatian across the Paratethys justifies stratigraphic correlation; 2) the fossil content of the "*Congeria rhomboidea* horizon" in Hungary and that of the Pontian layers in southern Russia are also so close that their correlation is warranted; and 3) as a consequence, the middle and upper Sarmatian and Maeotian of Russia corresponds to that part of the Hungarian Pannonian succession that lays below the C. rhomboidea horizon. He emphasized that further efforts are necessary to understand the details of correlation, but he was convinced that the hard part of the work had been done.

The above outlined correlation seemed logical at that time, and it was embraced mostly in those countries where both the Pannonian and Eastern Paratethys domains were present (Yugoslavia, Romania). In Hungary, however, the uniformity and continuity of Lake Pannon deposits was emphasized, and the introduction of the Pontian Stage as an official chronostratigraphic unit in the Pannonian Basin was met with resentment by many stratigraphers.

In the 21st century, magnetostratigraphic and radiometric dating of the Pontian Stage in the Eastern Paratethys showed that it represents only a short time interval between 6 and 5 Ma, covering the latest Miocene and, possibly, the earliest Pliocene. In the Pannonian Basin, however, this interval roughly corresponds to a tectonically induced, widespread stratigraphic gap. Pontian-equivalent deposits in the Pannonian Basin occur only deeply buried in those restricted basins, which have been subsiding and accumulating sediments since at least the early Late Miocene (e.g., central Alföld).

The stratigraphic gap between the Miocene and Pliocene is rarely accessible in the surface. A possible candidate is the unconformity that separates older, deep-water Pannonian marls from much younger, possibly ?Pliocene deltaic deposits in the Krndija Hills (Našice) and in the Fruška Gora (Beočin).

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Timing and mode of initial marine flooding in southern Pannonian Basin

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Hundred years after Vladimir Laskarev's designation of the term Paratethys for the huge inland sea at the northern flank of the Alpine-Himalayan orogen, a dispute on timing and mode of its environmental dynamics is still ongoing. In particular, an exact age for establishing marine setting in certain parts of the Pannonian Basin, including Miocene of Belgrade where the Paratethys term was coined, is still under discussion. Thereby the latter deposits mark the end of the long-lasting terrestrial phase initiated by the Adria-Alcapa collision in the Eocene. Although, the latter event essentially provoked the birth of Paratethys Sea in the Oligocene, it lasted more than 20 Myr until this sea reached the Dinarides again.

Its isolated condition triggered an adaptive radiation of captured biota facilitating the early biogeographic recognition as bioprovince, yet restricted migration from the open ocean mostly prevented establishment of shared bioevents and therewith the biostratigraphic dating. However, the initiation of Pannonian Basin between the Dinarides, Alps, and Carpathians, adjoined by the Slovenian gate activation in the late Early Miocene enabled not only environmental turnover of the long lived terrestrial and lacustrine settings into marine ones, but also a massive immigration of Mediterranean biota into the Paratethys. In particular, current advances in global and Mediterranean calcareous plankton stratigraphy establishing radiometric and astronomical calibration of the shared bioevents, permitted a precise reconstruction of a NW-SE prograding transgression in the southern Pannonian Basin along the internal Dinarides flank. This reconstruction is meanwhile backboned by increasing number of radiometric ages for terrestrial as well as for marine deposits, sound constraining the initial gradual flooding interval to late Burdigalian–early Serravallian and Karpatian–late Badenian, respectively, attaining up to 3 Myr overall duration.

Ostracods and mollusks from late Neogene Livno and Tomislavgrad paleolakes

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During Miocene, a multitude of intramontane basins emerged within the Dinarides mountain range. The basins were filled with a series of long-lived lakes, termed as the Dinarides Lake System (DLS), harboring endemic lacustrine fauna. The Livno-Tomislavgrad Basin hosted one of the principal lakes within the DLS. The basin infill of lacustrine sediments is separated by erosional boundary into two distinct lacustrine cycles reflecting the Livno-Tomislavgrad basin evolution. During the 1st cycle, basin hosted the long-lived Lake Livno. The 2nd cycle records lake separation in two depocenters, i.e. Livno and Tomislavgrad basins. The 2nd cycle consists of two depositional subcycles: the lower subcycle comprises white marls, whereas the upper subcycle includes two lithological units. The 1st unit - a coal series, is characterized by alternating layers of lignite and clays, and the 2nd unit is a variegated series composed of layers of clays and sands with limestone concretions. To correlate these two units, sampling and analysis included Table (central part of the Livno Basin) and Kongora (the eastern margin of Tomislavgrad Basin) sections which are providing the information about first and second unit, respectively. The table section, composed of three partial sections, comprises alternating lignite and clay layers bearing ostracod and mollusk fauna. The ostracod fossils belong to Candonidae and Cyprididae, whereas mollusk fauna is represented by gastropod family Melanopsidae. The Kongora section superposing the lignite layers, is composed of silty clay and poorly sorted conglomerate. The mollusk fauna of this section consists of remains of minute shells comprising sphaeriid bivalves and planorbid gastropods. The documented ostracods of Kongora are represented by three families Candonidae, Cyprididae and Ilyocyprididae.

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Upper Miocene aragonites of the Eastern Paratethys (Taman Peninsula)

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In the upper Sarmatian and the lower Maeotian of the Zheleznyi Rog section (Taman Peninsula, Eastern Paratethys), a series of thin aragonite layers were identified. These aragonites were investigated by field observations as well as laboratory methods, including scanning electron microscopy (SEM), X-ray diffraction and isotope analyses. The studied aragonite layers are characterized by predominantly sharply defined, planar bottom and top surfaces and are traced along the strike. These layers are generally about 1–3 mm thick and can be considered as laminae. Aragonite laminae form single intervals (1–2 m thick) of rhythmic alternation with mm-thick layers of clay. According to X-ray diffraction analysis, the upper Sarmatian aragonite laminae contain aragonite (87 %), calcite (5 %) and quartz (8 %). The aragonite (62 %), quartz (15 %), plagioclase (8 %) and jarosite (15 %) are identified in lower Maeotian aragonite laminae. The SEM data show that the aragonites of the upper Sarmatian consist predominantly of needle-shaped, twinned crystals and clusters of aragonites. The aragonite layers of the lower Maeotian consist predominantly of aragonite aggregates. These aragonite crystals, clusters and aggregates typically range in size from 5–6 to 23 μm. Aragonites from the upper Sarmatian and the lower Maeotian show values $\delta^{13}C$ = 5.7 ‰, $\delta^{18}O$ = –2.4 ‰ and $\delta^{13}C$ = 5.3 ‰, $\delta^{18}O$ = –2.8 ‰ (VPDB), respectively. It is assumed that the isotopic composition of aragonites reflects the sedimentation conditions, characterized by reduced (compared to normal marine) basin salinity, increased surface water bioproductivity, and periods of aridization. The idiomorphic form of aragonite and the absence of signs of mechanical transport of these particles (no clasts of aragonite crystals) in the studied layers do not allow them to be classified as mechanically redeposited sediments. In the aragonite sediments, the biogenic genesis of rock-forming components was not identified. The absence of oriented crystal growth, extent of aragonite layers along the strike, and the sporadic development in studied sedimentary succession do not confirm the possible initial diagenetic origin of these carbonate minerals. Abiotic precipitation of these aragonites most likely occurred due to the action of triggering mechanisms, which could include planktonic algae blooms (e.g. diatoms). It is suggested that the studied aragonites may represent sediments of mysterious whiting events, indicating a specific combination of various factors.

The fish fauna of the late Badenian (Middle Miocene) Medobory Barrier Reef in Ukraine reconstructed by means of otoliths

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The Medobory Reef was a short-lived, about 300 km long barrier reef in the Precarpathian Foredeep in western Ukraine and southeastern Poland during the late Badenian (Middle Miocene, early Serravallian). Reef fish communities are rarely encountered in the fossil record. Furthermore, the Medobory Barrier Reef is unique for its position in a geological time just after the Paratethys had become separated from the world ocean and after a major environmental crisis, the Karaganian / middle Badenian crisis, had occurred. Normal marine conditions were briefly re-established after the crisis during the Konkian / late Badenian and gave rise to the growth of the Medobory Barrier Reef near the northern limit of temperature conditions suitable for coralline-algal growth.

Because of the forgoing environmental crisis, the fish fauna was diminished in the Paratethys and repopulation through an ephemeral connection in the west with the Mediterranean apparently led to only little remigration. Thus, survivors of the environmental crisis and trapped in the Paratethys had the opportunity to adapt to the new reef environment, several among them that are not typical for today's reef environments. One group that was particularly successful in this setting was the Gobiidae, which are known for their ecologic tolerance and rapid adaptability. Most of the sampling was done in near-reef / back-reef positions in varying micro-environments. Even though the primary composition of the fish fauna is very similar across the seven sampled locations, minor changes in abundance, juvenile versus adult ratios, and changes of accessory elements indicate faunal differences putatively related to micro-environmental settings.

Sarmatian bivalves from silicificated sandstones and silica-ferruginous coquinas at the Chełm hills (Lublin Upland, Poland)

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The Chełm hills (*Pagóry Chełmskie*) occurring in the northeast part of the Lublin Upland form a specific complex of landforms. Small isolate hills formed by marly Cretaceous deposits and covered by Sarmatian strata have a character of inselbergs. Exposed approximately 100 km northeast of the Roztocze Hills (tops of which are composed of Sarmatian serpulid-microbialite reefs), this is the northernmost occurrence of Sarmatian sediments in the Paratethys. Previously mostly carbonates they are completely silicificated and their bivalve fauna is preserved in excellent impressions and natural moulds. No specimens show traces of calcite.

The study is focused on the determination of bivalve fauna collected from two small sandpits near the Chełm town: Czułczyce and Wereszcze Duże. The fauna comes from isolated irregular fragments of sandstones, which during diagenetic processus occurring during and after regression of the Sarmatian Sea, leached the calcium carbonate and replaced it with silica.

The bivalve fauna displays low diversity and is highly dominated by representatives of the genus *Ervilia*. Due to the state of preservation, it is extremely difficult to say whether all the specimens belong to *Ervilia podolica* (Eichwald) or some of them represent *Ervilia trigonula* Sokolov. Both species have been documented in the Sarmatian sandy sediments of the southern slopes of the Holy Cross Mountains. Representatives of the subfamily Lymnocardiinae are less numerous. Their shell outline and perfectly preserved characteristic radial ornamentation casted with silicon indicate *Obsoletiforma vindobonensis* (Laskarev). Most likely, specimens of this species were previously identified by Pusch (1837) as *Cardium protractum* Eichwald. The occurrence of two other bivalves: *Plicatiforma latisulca* (Münster) and *Polititapes tricuspis* (Eichwald) is very scarce. But it is these species that define the age these deposits as the latest Volhynian–early Bessarabian.

The Sarmatian sediments were formed during the regression phase of the Sarmatian Sea. According to Turnau-Morawska (1950), the cementation of the top parts of sandy sediments with preserved voids left by the bivalve fauna took place in coastal drying bays. The current top surface of these isolated hills is a slightly changed sedimentary surface. Due to their hardness, Sarmatian silicificated sandstones have been used in this region of Poland for purposes construction since the Neolithic period.

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A unique serpulid–bivalve association: A case study from the Medobory (western Ukraine, Paratethys)

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The middle Miocene Medobory reefs, unique bioconstructions in the Paratethys, are distributed widely (ca 300 km) along the SW margin of the East European Platform in western Ukraine and northern Moldova. Two generations of reefs, the Upper Badenian and the Lower Sarmatian (Volhynian) are separated by a sharp erosional boundary.

The time span in which they originated was unique in the history of the Paratethys. In the latest Badenian, the connection towards the Mediterranean Sea was interrupted, resulting in a drastic change of environmental conditions that ceased the growth of the Badenian coralline algal-vermetid reefs. The connections of the Intra-Carpathian basins with the Fore-Carpathian basins were severely restricted, and the latter gained a wide connection to the Eastern Paratethys, becoming its marginal part.

The younger (Sarmatian) generation of the Medobory reefs, originated in an extremely stressed environment associated with semi-marine conditions with fluctuating mesohaline salinity and elevated alkalinity, are composed of an unusual assemblage of skeletal organisms (serpulids and bryozoans) and microbial calcite precipitates. They Sarmatian reefs cover the western slopes of the Badenian reefs and rarely their tops. They also occur at the south-western foot of the Badenian reefs, forming isolated mounds, usually aligned more or less perpendicular to the older reefs.

The Sarmatian reefs exhibit a very peculiar composition and internal structure. They are composed of dome-shaped massifs built of carpets of incrusting organisms (mainly serpulids, rarely bryozoans), overgrown with microbialites (and often also synsedimentary cements). The co-occurrence of serpulids and microbialites in rock-forming quantities in the Early Sarmatian Paratethys is a unique phenomenon in the fossil record. Serpulids played a key role in the construction of the reef framework of the Sarmatian reefs. They formed dense aggregates that produced a stable substrate suitable for the settlement of byssate bivalves such as *Musculus sarmaticus* (Gatuev) and *Mytilaster volhynicus* (Eichwald). Furthermore, the occurrence of *Obsoletiforma volhynica* (Grischkevitsch) is largely restricted to the serpulid-microbialite framework consisting of superimposed bunches of semi-parallel serpulid tubes covered with microbialitic crusts. The latter species may show similar behavior to *Musculus sarmaticus,* which co-occurs with it wherever the environmental condition have been sufficient to allow the growth of densely packed serpulid colonies that provide shelter for byssally attached bivalves. In addition, *Crassostrea gryphoides* (Schlotheim), whose shells are common in Neogene strata and often form huge clusters in coastal environments, produces here, together with densely packed serpulid tubes, massive, raised biostructures up to 3 m high.

Late Badenian transgression in the north-western Podolia Upland (western Ukraine, Central Paratethys)

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This study presents the results of biostratigraphical and sedimentological research conducted in the Voronyaky Hills, which form the north-western borders of the Podolia Upland. The sites of Oles'ko-Bila Hora, Yaseniv 1, Yaseniv 2, Voluiky and Zelena Hora were selected for research where two types of sediments are observed. 32 samples were collected for micropaleontological research: 19 samples from the carbonate facies and 13 ones from the sandy facies.

The transgressing Late Badenian Sea entered an area with a diversified relief, eroded in the Senonian marls. These deposits are dominated by quartz sands and sandstones, which have been known for their fossil content since the 19th century, and coralline algae marls with intercalations of limestones and rhodoliths. On the basis of strontium isotopes in bivalve shells from the Oles'ko-Bila Hora site, the age of the deposits was estimated at 13.6 Ma, which corresponds to the Late Badenian (early Serravallian). The thickness of the sands overlying the Senonian marls, varies greatly and reaches a maximum of about 20 m (Oles'ko-Bila Hora and Voluiky), while the thickness of the marls does not exceed 8 m (Yaseniv).

The sandy deposits initiating the Badenian sedimentation were originated generally in a higher energy environment (cross bedding, ripple lamination); in places, numerous bioturbations are also common. The sands contain a rich assemblage of normal marine fauna, dominated by bivalves (about 80 species) with excellently preserved aragonitic shells represented either by disarticulated or articulated valves. The foraminifer fauna represented by 25 benthic species is the most diverse within the middle part of the Oles'ko-Bila Hora section. The foraminifers indicate a shallow water marine environment associated with the marginal zone of the basin (upper sublittoral zone) with well oxygenated bottom waters.

The marly deposits from the upper part of the Badenian section were deposited in a lower energy depositional environment. Only a few bivalve species were found, with one dominant species *Glans trapezia*, whose originally aragonitic shells are preserved as moulds or imprints. The foraminifer assemblage represented by 75 benthic species indicates both deepening environment (lower sublittoral zone) and decreasing oxygenation of the bottom waters.

Did the Dinaric Alps force an arid climate and speciation during the Miocene Climatic Optimum?

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Significant uplift of large mountain ranges such as the Andes and Himalayas has been demonstrated to be connected to local climate change, leading to contrasting depositional environments and fauna speciation across the range. We test the hypothesis that this relationship exists and affects deposition and speciation to a similar degree in lower mountain ranges such as the Dinaric Alps (Dinarides) in SE Europe.

This hypothesis will be tested by a systematic U-Pb dating of tuff layers and carbonate sediments in the different Miocene intramontane basins across the mountain range, together with the reconstruction of depositional environments. These reconstructions will be supported by a detailed study about the temporal and spatial distribution of the fauna and flora in different basins.

Integration of our new radiometric ages with existing data, mostly from the external part of the Dinarides, will allow us to make detailed correlations of sedimentary successions and paleoenvironments in isolated basins across the Dinaride orogen, as well as to present a critical evaluation of hypothesised causal relationships between its Miocene uplift, the strengthened regional climate gradient, and a diverging adaptive radiation of its biota.

Late Miocene land vertebrate faunas from the Eastern Paratethys area

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The Late Miocene record of the continental vertebrates has rich record in the North of the Eastern Paratethys. The territories of Romania, Moldova, Ukraine, and Southern Russia provide with continental and partially marine deposits which contain also horizons of bone remains including all vertebrate groups. Age of these deposits have been largely dated by previous extensive studies from Sarmatian s.l. to Maeotian. In most cases, the ages of sites are poorly constrained, making the paleobiogeographic, -geographic, -environmental, and -climatic reconstructions and analyses in time and space extremaly difficult and vague.

Our new study aims to reassess the ages of the known sites and document new sites with vertebrate faunas using a multidisciplinary approach. Our field studies, we could not confidently relocate the earlier known sections and fossiliferous horizons. Thanks to our new field observations and sampling, we have able to redescribe the sections and resampled for further analyses and studies. For more than ten sites of Bessarabian to Maeotian ages, a broad range of proxies such as sedimentological description, relative dating (magnetostratigraphy, micropaleontology, mollusc biostratigraphy, cosmogenic nuclides), and vertebrate palaeontology has been applied.

The sections represent mostly fluvial deposits of the Balta Formation, but they included also deposits from the shore and/or deltaic environments. These sediments provided mostly vertebrate assemblages. Mammalian biochronology and biostratigraphy of marine groups have been used to correlate the superpositions of the sites and faunas. Amphibian and reptilian assemblage allowed to reconstruct the paleoprecipitation values.

Petrological and geochemical composition of lignite from the Zabela-Kosa deposit, Despotovac basin (Serbia)

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Petrological and geochemical investigation of lignite were performed on core samples from the Zabela-Kosa deposit, Neogene Despotovac basin, located about 130 km southeast of Belgrade (Serbia).

The lignite from the Zabela-Kosa deposit (Despotovac basin), is a typical humic coal with huminite, liptinite and inertinite concentrations of up to 71.6 vol.%, 9.7 vol.% and 6.8 vol.%, respectively. Ulminite and densinite are the most abundant macerals of huminite group with variable amounts of textinite, attrinite and corpohuminite. The content of gelinite is low. Liptodetrinite and sporinite are the most common macerals of the liptinite group, with elevated content of sporinite, resinite and cutinite. Alginite and bituminite are detected in several samples. Inertodetrinite is the most common maceral of the inertinite group. The mineral matter consists mostly of carbonate and clay minerals with variable content of pyrite.

The biomarker composition of aliphatic and aromatic fraction implies that main sources of organic matter of lignite from the Zabela-Kosa deposit, Despotovac basin were gymnosperms (conifers) with variable amount of angiosperms. The presence of tetracyclic (phyllocladane) and tricyclic diterpenoids, as well as C_{15} sesquiterpenoids in aliphatic fraction indicates the families of Phyllocladaceae, Pinaceae and Cupressaceae as precursors of lignite organic matter. Non-hopanoid triterpenoids with oleanane and lupane skeleton imply contribution from angiosperm vegetation. Composition of aromatic fraction represented by sesquiterpenoids (calamenene, cadalene), diterpenoids (simonellite, dehydroabietane, norabieta-6,8,11,13-tetraene), as well as non-hopanoid triterpenoids (3,3,7-trimethyl-1,2,3,4-tetrahydrochrysene, 24,25-dinorlupa-1,3,5(10)-triene) confirms an immature terrestrial organic matter derived from gymnosperms and angiosperms.

SESSION 2

The history of geology and concept of the Paratethys by V. Laskarev

Vladimir Dmitrievich Laskarev (1868–1954): Life and Work

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Vladimir Laskarev was a prominent Russian and Serbian scientist, geologist and palaeontologist, full member of the Serbian Academy of Sciences, full professor at the University of Belgrade, and a long-time associate of the Natural History Museum.

Laskarev was born on 26 June 1868 in Biryuch. After school education obtained in Biryuch and Chernigov, he studied natural sciences at the Imperial University of Novorossiysk in Odessa where he was appointed assistant in geology after graduation. He was elected private-docent (1901) and obtained a master's degree in geognosy and mineralogy (1903). In 1904, he was elected to the position of professor at the Geology Department of the Novorossiysk University in Odessa. He defended his doctoral dissertation "Geological Research of South-Western Russia" at the University of Kiev (1916), obtaining the title of Doctor of Geological Sciences. The October Revolution and the Civil War interrupted Laskarev's research work and successful career. Together with his sister and her children, Laskarev left Russia in January 1920. By his own will, and at the invitation of the Serbian scientists, he arrived in Belgrade as early as on 5 May 1920. Shortly after settling in Belgrade, Laskarev became a member of the Serbian Geological Society, where he often gave lectures.

His extremely wide scientific opus can be grouped into two periods: first in Russia, and then in Serbia. During the first period, he was engaged in geological research in southwest Russia, studying the formations in Podolia and Bessarabia, the sediments of the Sarmatian Sea in the Volyn, Podolsk and Kiev Governorates, the tectonics of the crystalline mass, as well as the rich fossiliferous deposits in southern Russia. In Serbia, he devoted his research mainly to the stratigraphic studies of Neogene and Quaternary formations. His professorship at the Institute of Geology and Palaeontology, the Belgrade University, also covered a wide geological range. He taught specialist courses: History of Cenozoic, Palaeontology, Introduction to Independent Geological and Field Work. In 1932, Laskarev was elected a corresponding member of the Serbian Royal Academy, and in 1947 he became its full member. One of Laskarev most important contributions was his paleogeographic idea on a large Neogene epicontinental sea extended from the Alps and Central Europe to Inner Asia that he named Paratethys.

During his long and prolific lifetime, Laskarev was honoured with numerous awards for his work. As a quiet, modest, and unobtrusive person, he was deeply respected and beloved colleague and teacher. Laskarev died on 10 April 1954 in Belgrade, after a long and debilitating illness, and was buried in the Russian part of Belgrade's New Cemetery.

The Paratethys – From a historical concept to present challenges

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Vladimir D. Laskarev, a prominent Russian and Serbian geologist and palaeontologist, was the first one who officially introduced term "Paratethys" for a great epicontinental sea which extended from the Alps and Central Europe to the Inner Asia and present-day Kazakhstan. During the 209th Session of the Serbian Geological Society (April 10, 1924) he gave a lecture entitled "On the Congerian layers and their significance for the tectonics of the Belgrade". In same year, the lecture firstly published in French as" Sur les équivalents du Sarmatien Supérieur en Serbie " in a collection of papers dedicated to the 35th anniversary of the scientific activity of his colleague and friend Jovan Cvijić, world-known karstologist. The Paratethys was born! It was a last step of almost thirty years old a hypothesis that occupied him. Namely, since the first professional step as a field geologist in southern Russia (1896), and over several years of professional trips in Western and Central Europe (1898-1900), an idea about the existence of the ancient European sea was born in his mind. Tectonic observations in the Miocene throughout Alps, Central Europe, and south-western Russia, lectures he listened by E. Suess, T. Fuchs, A. Karpinsky, N. Andrusov and other famous geologists of the time, and a particularly careful and detailed review of Neogene mollusc collections in the museums throughout Europe, strengthened in him an idea on a large epicontinental sea called the Paratethys. However, during the first three decades since an official introduction the term did not have wide usage. The beginning of its widespread use was initiated after the foundation of the Regional Committee on Mediterranean Neogene Stratigraphy (RCMNS, 1958) and since it's the 1st Congress in Vienna (1959). Finally, after the formation of the Paratethys Working Group during the 4th Congress of RCMNS (Bologna, 1967) the term is widely accepted. During the 1970s, the term was universally known after the International Geological Correlation Project (IGCP) No. 25 "Stratigraphic correlation Tethys - Paratethys Neogene" (leader Jan Seneš). At the same time, the regional stratigraphic scale of the Central Paratethys was established and the Andrusov's horizons of the Eastern Paratethys were elevated to the rank of regional stages. Since then, the term Paratethys has become one of the most widespread terms in geology, and that trend continues to the present day.

Compared to Laskarev's time, the new scientific methods and an interdisciplinary/multidisciplinary approach led to new scientific knowledge regarding Paratethys and its evolution. Modern and upgraded techniques, high-resolution field sampling, and fine processing by sophisticated lab equipment resulted in the integrated stratigraphical as well as palaeogeographical reconstructions of the Paratethys. Now that this lecture has been given, dozens of new scientific papers on various aspects of Paratethys are being printed or waiting to be printed in journals worldwide.

The legacy of Vladimir Laskarev in the Natural History Museum

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Vladimir Laskarev (1868-1954), Russian and Serbian geologist, member of the Serbian Academy of Sciences and Arts and manager of the Geological Institute of the Serbian Academy of Sciences and Arts.

Thanks to the efforts and enthusiasm of Professor Laskarev, the Natural History Museum in Belgrade has one of the most beautiful and extremely valuable collections of large fossil mammals. In the period from 1921 to 1929, as a volunteer curator of the Natural History Museum of Serbian Land, Laskarev was working on excavating and processing the fauna of Pikermi mammals from the vicinity of Veles (Northern Macedonia). The research was carried out by Laskarev and the director of The Natural History Museum of Serbian Land, Petar Pavlović, together with numerous collaborators.The field work was led by Laskarev himself, who simultaneously with the excavations was working on the determination, reconstruction and inventory of materials. Already during the first excavations, it was clear that this was an extremely rich geological site. The presence of at least 20 species of fossil large mammals has been determined, among which the most numerous are three-toed horses, antelopes, pigs, giraffes, proboscids, primates, rhinoceroses, hyenas, etc. During the years of excavation, Pikermian fossil material grew to over 3000 specimens and today represents one of the most important collections within the Collection of Paleogene and Neogene large mammals of the Museum of Natural History in Belgrade.

During the eight-year collaboration, Pavlović and Laskarev were collecting malacofauna of the Pontian age in the vicinity of Belgrade: *Limnocardium banaticum, Kaladacna steindacneri,* etc. and the Oligocene fauna of North Macedonia: *Bayania stigii, Cerithium semigranosum,* etc. Laskarev published notes on the loess sediments of the Belgrade area and by finding beds with *Corbicula fluminalis* and mammals, he established fluvial lacustrine sediments of the oldest Pleistocene. Laskarev collected more than 30 species (262 exemplars) in the fund of the Collection of Cenozoic Invertebrates from several localities: Bačko Petrovo Selo, Titelski breg, Arandjelovo and others. Laskarev wrote about the Quaternary of Vojvodina and introduced the terms "Belgrade deposits" and "Makiš deposits" into science.

The above results are just some of the examples of Laskarev's achievements, which even today represent the basis for future scientific research in the field of Quaternary. Petar Pavlović expressed his gratitude, respect and friendship for Laskarev by naming a new Neogene species *Pyrgula laskarevi* Pavlović.

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