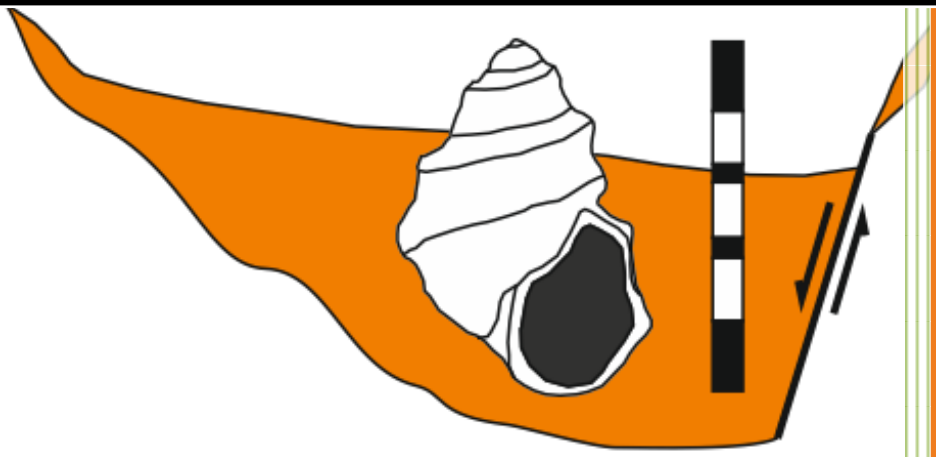
20–24 May 2016
Zagreb / Croatia

RCMNS Interim Colloquium 2016
Croatian Geological Society Limnogeology Workshop

Lake – Basin – Evolution



Program & Abstracts

Zagreb 2016

RCMNS IC 2016 & CGS Limnogeology Workshop

LAKE - BASIN - EVOLUTION

20 - 24 May 2016, Zagreb, Croatia

RCMNS Interim Colloquium 2016

Croatian Geological Society Limnogeology Workshop

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Lake – Basin – Evolution

Stratigraphy, Geodynamics, Climate and Diversity of Past and Recent Lacustrine Systems

Program & Abstracts

Hrvatsko geološko društvo / Croatian Geological Society
Zagreb 2016
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Preface

Lacustrine basins are dynamic depositional systems depending on regional climate and geodynamic settings. Their isolation may lead to diversification of endemic faunas that complicate biostratigraphic correlations and palaeoecological assessments. Even today, age constraints for a number of prominent lacustrine complexes are inadequately resolved. Improved time resolution relies on the thorough integration of multiproxy data.

For that reason, the Regional Committee on Mediterranean Neogene Stratigraphy (RCMNS) decided to devote a special Interim Colloquium to this particular topic. The Dinarides area of Croatia provides the ideal geological setting of an active fold and thrust belt that separated the Mediterranean and Paratethys basins and recorded an extended history in lacustrine deposition. Those basins offer spectacular examples how geodynamic processes controlled duration and depositional modes in lacustrine systems. Several of the Neogene-Quaternary lakes became evolutionary hotspots. Large-scale research projects such as the Lake Ohrid deep drilling (SCOPSCO, PI Thomas Wilke), the Freshwater Gastropods of the European Neogene (FreshGEN, PI Mathias Harzhauser), the Pontocaspian biodiversity Rise and Demise (PRIDE, PI Frank Wesselingh), and the Evolution of the Paratethys (NWO, PI Wout Krijgsman) show the interest in lacustrine systems and biotic evolution within.

The Croatian Geological Society (CGS) represents the key partner responsible for the on-site organization of this meeting, which became integrated into its CGS Limnogeology Workshop. Beside RCMNS and CGS as parent organisations, a great number of national and international scientific bodies and companies became active supporters and sponsors of the meeting – University of Zagreb (Faculty of Mining, Geology and Petroleum Engineering, Faculty of Science), Croatian Natural History Museum, Natural History Museum Vienna, INA-Industrija nafte, Zagreb Tourist Board, Croatian Geological Survey, Croatian Academy of Sciences and Arts, International Union of Sedimentologists, and International Union of Geological Sciences.

The 2016 RCMNS Interim Colloquium and CGS Limnogeology Workshop will bring together a variety of experts and disciplines in lacustrine basin research. Stratigraphers, sedimentologists, structural geologists, paleontologists, biologists and geochemists will present current results from their ongoing research and will share their experience. This will lead to new cooperations still better integrating the constantly growing knowledge toward a new synthesis of the still underexplored field of limnogeology.

The Organization Team

Program

Friday, 20 May 2016

EXCURSION 1
NW Croatia (Mt. Medvednica – Hrvatsko Zagorje – Zagreb)

08:00 Meeting point - Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Pierottieva 1 (45.806911, 15.964327)

OPENING CEREMONY
Croatian Natural History Museum, Demetrova 1

18:30 Registration

19:00 Welcome notes by organisors and umbrella organizations
Oleg Mandic – Organisation Committtee
Wout Krijgsman – Regional Committee on Mediterranean Neogene Stratigraphy
Lilit Cota – Croatian Geological Society

19:15 Welcome notes by sponsors
Niko Dalić – INA (Industrija nafte, d.d.)
Zoran Nakić – RGN (Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb)
Jasenka Sremac – PMF (Faculty of Science, University of Zagreb)
Josip Halamić – HGI (Croatian Geological Survey)
Ivan Gušić – HAZU (Croatian Academy of Sciences)
Tatjana Vlahović – HPM (Croatian Natural History Museum)

19:45 **PLENARY LECTURE • Mathias Harzhauser**: History of European lake systems – evolution, geodynamics, and climate change

20:30 **Katarina Krizmanić**: Introduction to Croatian Natural History Museum

20:45 Ice breaker party and guided tours

Saturday, 21 May 2016

PRESENTATIONS AND POSTER SESSIONS
Faculty of Mining, Geology and Petroleum Engineering, Pierottieva 1

08:00 Registration

Session A. LIMNOGEOLOGY – RECENT LAKES AS BIOTIC AND CLIMATE ARCHIVES

Chair: Nada Horvatinčić

08:30 **KEYNOTE • Thomas Wilke**: Drilling the oldest lake of Europe – deep-time evolutionary and environmental archive Lake Ohrid

09:00 **Adele Bertini**: Palynology as an indicator of paleoenvironmental and paleoclimatic changes at Lake Ohrid (south-eastern Europe) during the past 500 ka

09:15 **Claudia Wrozyna**: Shape variation in Neotropical *Cytheridella* using semilandmarks-based geometric morphometrics: a methodological approach

09:30 **Anastasia G. Yanchilina**: The change in the elevation of the Bosporus sill during the last deglaciation and its role in the delay of the early Holocene marine transgression of the Black Sea-Lake

09:45 **Slobodan Miko**: Late Quaternary Evolution of Lakes and submerged paleo-karst on the Eastern Adriatic

10:00 **Elisavet Georgopoulou**: European Quaternary: Insights from freshwater gastropods

10:15 Coffee break & Poster session A-B

Session B. PALEOBIOLOGY – DIVERSITY AND ENVIRONMENTS IN PAST LACUSTRINE ECOSYSTEMS

Chair: Mathias Harzhauser

11:00 **KEYNOTE • Frank P. Wesselingh**: Evolution and biodiversity change – lessons from Amazonian and Pontocaspian Lake Basins

11:30 **Yeşim Büyükmeriç**: Quaternary Pontocaspian lake phases in the Marmara Sea Basin

11:45 **Martin Gross**: A minute ostracod (Crustacea) from the Miocene Solimões Formation (western Amazonia, Brazil) – Evidence for marine incursions?

12:00 **Andrzej Pisera**: The Biota of an Arctic Eocene Maar Lake During a Greenhouse Environment with an Emphasis on the Sponge

12:15 **Gordana Jovanović**: Mollusks and ectothermic vertebrates from the Middle Miocene (Sarmatian) Lake Vračević (Serbia)

12:30 **Thomas A. Neubauer**: Predictors of shell size in long-lived lake gastropods

12:45 Lunch break at Faculty of Mining, Geology and Petroleum Engineering & Poster Session A-D

Session C. STRATIGRAPHY / HISTORICAL GEOLOGY

Chair: Imre Magyar

14:00 **KEYNOTE • Wout Krijgsman**: Dating the lake histories – integrated stratigraphy and correlation of isolated paleoenvironments

14:30 **Karin Sant**: A middle Miocene age for the Popovac Lake (Serbia): Ar/Ar dating and magnetostratigraphy in the Serbian Lake System

14:45 **Miguel Garcés**: Long-term Sedimentary Trends of Neogene Lake Systems of the Iberian Plate

15:00 **Wilma Wessels**: Rodent assemblages from the early Miocene and Oligocene of Bosnia Herzegovina and Serbia

15:15 **Krisztina Sebe**: Linking bio- and chronostratigraphy in Lake Pannon: pyroclastics and biozones in the southwestern Pannonian Basin

15:30 **Ljupko Rundić**: Pliocene lake deposits and the Pliocene/Quaternary boundary at the Fruška gora (Serbia): an integrated study

15:45 Coffee break & Poster session C-D

Session D. GEODYNAMICS – SEDIMENTARY SYSTEMS

Chair: Davor Pavelić

16:30 **KEYNOTE • Liviu Matenco**: Lake basin evolution dynamics – tectonic control of depositional processes in isolated settings

17:00 **Nevena Andrić**: The link between tectonics and sedimentation in asymmetric extensional basins: inferences from the study of the Sarajevo-Zenica Basin

17:15 **Doris Groß**: Geodynamic controls of organic matter deposition in lacustrine basins: The case of Miocene pull-apart basins in the Eastern Alps

17:30 **Krešimir Krizmanić**: Lake Pannon sedimentation model in the Legrad field area (NW Croatia)

17:45 **Nadja Zupan Hajna**: Age of karst sediments in SW Slovenia

18:00 **Emő Márton**: Tectonically oriented paleomagnetic study of the Pag and Drniš-Sinj intramontane basins, External Dinarides

CLOSING CEREMONY

18:15 **Koraljka Bakrač** / **Marijan Kovačić**: RCMNS IC 2017

18:25 Notes by organisators and and umbrella organizations / Discussion
Oleg Mandic: Conference summary, proceeding volume and next venue
Wout Krijgsman: Note by RCMNS
Lilit Cota: Note by the Croatian Geological Society

18:45 Light drinks

SOCIAL DINNER

19:30 Location - Pivnica Medvedgrad, Ilica 49 (45.813146, 15.967988)

Sunday, 22 May 2016 – Tuesday, 24 May 2016

EXCURSION 2
Croatia and Bosnia-Herzegovina (Plitvice – Vrana – Sinj – Livno – Tomislavgrad – Kupres – Bugojno - Kakanj)

08:00 Meeting point - Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Pierottijeva ulica 1 (45.806911, 15.964327)

ABSTRACTS

PLENARY LECTURE

History of European lake systems – evolution, geodynamics, and climate change

Harzhauser, M., Neubauer, T.A., Kroh, A., Georgopoulou, E., Mandic, O.

Geological-Paleontological Department, Natural History Museum Vienna, Burgring 7, 1010 Vienna, Austria

The title of the current RCMNS Interim Colloquium links the biologic developments in past and recent lacustrine systems with abiotic factors such as climate and geodynamics. During the last years the FreshGEN working group tried to decipher these relations based on an extensive data collection on spatial and temporal distributions of Neogene to Recent freshwater gastropods. We chose gastropods as model organisms because these molluscs are speciose, systematically comparatively well understood and have a rich fossil record. The database allows studying the evolutionary patterns in individual lakes through time – e.g. in Lake Pannon – and to describe large-scale patterns on a European scale. Our data strongly indicate that geodynamics, respectively the formation and demise of large and long-lived sedimentary basins, is the main driving force in lacustrine biogeography. The large-scale changes of the community composition on the family level, differences of the relative species richnesses per biogeographic regions and the rising rate of endemism are all largely controlled by the varied presence of long-lived lakes. The underlying mechanism for this pattern is the ongoing continentalization of Europe triggered by the Alpidic Orogenesis and the simultaneous retreat of the Paratethys Sea. As shown by the alternation of the biogeographic regions through time, the changing shorelines of the Paratethys had a massive impact on the evolution of surrounding freshwater systems.

Climate, in contrast, was surprisingly less important in constraining lacustrine biodiversity. A major exception from this observation is the impact of the Pleistocene glacials. This dramatic event caused the near complete loss of caenogastropod-dominated lakes, which were often characterised by eye-catching radiations of hydrobiids and melanopsids. What remained after the crises were pulmonates-dominated lakes. Even these pioneer assemblages were hit by the expansion of the ice shields. Still, the distribution of European limnic gastropods at least partially carries the imprint of the last Ice Age. The differences in species richness and composition of modern lakes point toward a gradual, ongoing process of species recolonization after deglaciation. Hence, the Holocene biotic development in Europeans lakes is “work in progress”, which is strongly threatened by anthropogenic habitat destruction.

SESSION A. LIMNOGEOLOGY

KEYNOTE

Drilling the oldest lake of Europe – deep-time evolutionary and environmental archive Lake Ohrid

Wilke, T.

Justus Liebig University Giessen, Department of Animal Ecology and Systematics, Heinrich-Buff-Ring 26, 35392 Giessen, Germany

Ancient Lake Ohrid on the Balkan Peninsula constitutes the oldest and most biodiverse freshwater lake in Europe. The processes generating this amazing species richness with a high share of endemic taxa, however, are not fully understood.

In order to unravel the geological, environmental, and evolutionary history of the lake and to infer the influence of major geological and environmental events on the evolutionary trajectories of its endemic taxa, an international research initiative – the SCOPSCO drilling project – was launched. The project combines sedimentological, tephro-stratigraphical, seismic, and paleontological studies of lake sediment cores with molecular-dating and empirical modelling approaches applied to extant taxa.

Preliminary analyses of sediment core and borehole logging data from drill sites with a maximum penetration depth of 569 m below lake floor suggest that Lake Ohrid reached deep-water conditions c. 1.3 Ma ago. The age of its oldest sediments is c. 2.0 Ma. Moreover, seismic data, fossil information, and coarse-grained sediments in the basal cores revealed that Lake Ohrid had no marine origin, as it was speculated in the past. Interestingly, high-resolution data for the last 0.65 Ma so far do not indicate the occurrence of catastrophic environmental events, i.e., events that lead to sudden drastic regime shifts and thus potentially to mass extinction.

Combined evidence from geological, paleolimnological, and biological data suggest that the extraordinary biodiversity in Lake Ohrid is largely driven by i) the long and continuous existence of the lake, ii) the lack of catastrophic events during its lifetime, and iii) a high ecosystem resilience. The cumulative effect of these factors might have resulted in overall low extinction rates and continuous speciation events. These findings highlight the role of catastrophic or near-catastrophic events in shaping patterns of extant biodiversity in isolated ecosystems.

Palynology as an indicator of paleoenvironmental and paleoclimatic changes at Lake Ohrid (south-eastern Europe) during the past 500 ka

Bertini, A.[1], Sadori, L.[2], Combourieu-Nebout, N.[3], Donders, T.H.[4], Kouli, K.[5], Koutsodendris, A.[6], Joannin, S.[7], Masi, A.[2], Mercuri, A.M.[8], Panagiotopoulos, K.[9], Peyron, O.[7], Sinopoli, G.[2], Torri, P.[8], Wagner, B.[10]

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[3]*Département de Préhistoire, Muséum national d'Histoire naturelle, Institut de Paléontologie Humaine, Paris, France*
[4]*Palaeoecology, Department of Physical Geography, Utrecht University, Utrecht, The Netherlands*

[5]*Faculty of Geology and Geoenvironment, National and Kapodistrian University of Athens, Athens, Greece*
[6]*Paleoenvironmental Dynamics Group, Institute of Earth Sciences, Heidelberg University, Heidelberg, Germany*
[7]*CNRS UMR 5554, Institut des Sciences de l'Evolution de Montpellier, Université de Montpellier, Montpellier, France*
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[9]*Institute of Geography and Education, University of Cologne, Cologne, Germany*
[10]*Institute for Geology and Mineralogy, University of Cologne, Cologne, Germany*

Lake Ohrid (Balkan peninsula) is the deepest, largest and oldest extant lake in Europe. Such a unique, terrestrial natural archive is especially relevant for both paleoenvironmental and paleoclimatic reconstructions but also for genetic studies. In the frame of the International Continental Scientific Drilling Program (ICDP), a deep drilling campaign was carried out within the scope of the Scientific Collaboration on Past Speciation Conditions in Lake Ohrid (SCOPSCO) project in 2013. Here, we present the summary of palynological analyses carried out in the upper 200 m of the overall 569 m long DEEP site sediment succession from the central part of the lake. These studies, performed by an international palynological team, document the main floristic, vegetation and climate changes during the last ca 500 ka, at a millennial-scale resolution (~1.6 ka). The continuous sediment infill permitted to trace multiple non forested/forested phases as a response to glacial-interglacial cycles as well as to sub-Milankovitch climate changes. The pollen record, corresponding with marine isotope stages MIS 13 (p.p.) to MIS 1, points to a progressive change from cooler and wetter to warmer and drier interglacials. New palynological studies are underway to reconstruct vegetational and climatic conditions over older intervals as well as to obtain high resolution data for some key intervals such as MIS 5–6, MIS 11–12, MIS 35–42. The complete record of changes in flora composition and vegetational structure during both glacials and interglacials will furnish indispensable insights for understanding the role of refugia, ecosystem resilience and maintenance of terrestrial biodiversity in the Mediterranean area.

European Quaternary: Insights from freshwater gastropods

Georgopoulou, E., Neubauer, T.A., Harzhauser, M., Kroh, A., Mandic, O.

Geological-Paleontological Department, Natural History Museum Vienna, Burgring 7, 1010 Vienna, Austria

The first detailed study of Quaternary biogeographical patterns of freshwater faunas based on spatial and temporal analyses is presented. Six distinct time intervals of the Quaternary, i.e. Gelasian, Calabrian, Middle Pleistocene, Last Interglacial, Last Glacial and Holocene, were investigated. Turnover rates and potential differences in species richness were explored. Late Pliocene records were also included in order to evaluate the magnitude of the Plio-Pleistocene turnover. Changes in species geographical ranges among the predefined time intervals were checked for nested patterns using nestedness analysis.

398 freshwater gastropod species were recorded across 1129 European Quaternary localities. Species richness differed significantly among the studied time intervals, mainly reflecting the differences between the intervals' durations. Turnover was low among the Quaternary intervals, but high at the Plio-Pleistocene boundary. Species ranges were significantly nested in all time intervals; nestedness was highest for the Late Pleistocene and Holocene.

Highly endemic aquatic systems (e.g. the long-lived lakes Bresse and Tiberino) are re-

sponsible for increased species richness during the Early Pleistocene. Fluvial and/or lacustrine systems with short temporal durations mostly account for diverse assemblages of the Middle to Late Pleistocene and Holocene. The gradual loss of provincialism during the Quaternary is reflected in the decreasing turnover rate and increasing nestedness. The demise of long-lived lakes and their rich, endemic faunas at the end of the Pliocene is related to the Plio-Pleistocene boundary turnover event. The prevalence of generalist species with wide geographical ranges during the Late Pleistocene and Holocene is indicated by an increase of nestedness, paralleling the retreat of long-lived lakes and a declining speciation rate. Holocene patterns of species' distributions are a result of recolonization of formerly glaciated areas following deglaciation after the Last Glacial Maximum.

A sedimentary record of Late Pleistocene and Holocene environmental changes from lakes on the Eastern Adriatic coast *P*

Ilijanić, N., Slobodan, M., Ozren, H., Koraljka, B.

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

Lake sedimentary record was used to reconstruct paleoenvironmental changes during Late Pleistocene and Holocene along the Croatian karst region on the Eastern Adriatic. Lake sediments were studied using multidisciplinary approach, combining sedimentological, mineralogical and geochemical analysis with paleontological proxies like pollen, ostracods or diatoms and dated using radiocarbon absolute dating. The most of the lakes cover the end of Pleistocene and beginning of the Holocene and show the evolution of the lakes and environmental changes during the last 12.000 years. Paleolimnological research was conducted on lake sediments on the eastern Adriatic coast (Lake Vrana on the Island Cres, Bokanjačko blato, Lake Vrana near Biograd and Lake Baćina-Crniševo) and they enabled reconstruction paleoenvironmental conditions from the late Pleistocene until present. Due to the proximity of the sea and permeable karst, the lake levels are influenced significantly by the sea level rise during the Holocene. Lakes represent typical karst lakes dominated by carbonate sedimentation, with periodic siliciclastic input. In every lake, three periods can be distinguished, the beginning of the Holocene with increased erosion and higher concentrations of siliciclastic material, middle Holocene with formation of deeper lakes and carbonate sedimentation, and Late Holocene characterised by erosion of siliciclastic material as a result of deforestation and human impact. Deposition of the siliciclastic material in Lake Vrana near Biograd lasted until 9.1 ka BP, when carbonate lake sedimentation started and the lake was formed. At the end of the period from 9.6 to 9.1 ka BP the dark organic rich sediment was deposited. The marine influence on the Lake Vrana sediments is evident after 6.1 ka BP. The present lake water conditions (alternating seasonal changes in the salinity, freshwater-brackish) were established at 3.8 ka BP. Deposition of homogenous carbonate mud (lake marl) started at 3 ka BP. In Lake Baćina deposition of the siliciclastic material was very intense from 11.7 to 10 ka BP, and then gradually decline until 7.5 ka BP. Dominant carbonate deposition lasted from 7.5 until 4.5 ka BP, when intensive changes in the sediments began, observed by the high sand fraction until 2.5 ka BP, and in between the alternate intervals were developed with calcite and quartz and those in which only calcite is present. In Bokanjačko blato the deposition of siliciclastic material lasted from 10.3 to 6.1 ka BP and then gradually decreases until 5.2 ka BP, when carbonate deposition began. In Lake Vrana on the Island Cres, the beginning of the Holocene is characterized by the deposition of the siliciclastic material, but which continues to the middle

Holocene, until 4.5 ka BP when the carbonates appear. During the Holocene contrasting climate pattern has been identified in the central Mediterranean. Paleoenvironmental reconstructions of investigated lakes on the Eastern Adriatic coast correlate well with the lakes situated north of around 40°N of latitude, which are characterised by a wetter early Holocene, followed by relatively drier conditions during the middle Holocene and gradually increased moisture in the Late Holocene. South of 40°N of latitude there is opposite trend, very dry conditions in the first half of the Holocene and wettest period during the Mid Holocene followed by a progressive aridification, evident in lakes Preola and Pergusa on Sicily.

Late Quaternary evolution of lakes and submerged paleo-karst on the Eastern Adriatic

Miko, S.[1], Ilijanić, N.[1], Hasan, O.[1], Razum, I.[2], Durn, T.[3], Brunović, D.[1], Papatheodorou, G.[4], Bakrač, K.[1], Hajek-Tadesse, V.[1], Crmarić, R.[5]

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[5]Hydrographic Institute of the Republic of Croatia – Split, Zrinsko-Frankopanska 16, 21000 Split, Croatia

The Croatian coastal region is a part of Maritime Dinaric Alps which coincides with the Adriatic Carbonate Platform (AdCP). Some of the coastal karst depressions developed into larger lakes. Although not numerous (<10) these Holocene lakes are quite evenly distributed along the coast from Istria (Ćepić polje) in the north to the Baćina lakes and the Neretva river delta in the southern part of the Croatian Adriatic coast. Due to the permeable nature of karst some of the coastal lakes never developed as freshwater bodies (Veliko jezero, Mljet Island). Sediment core records show a tight correlation between sea level rise and lake formation during early Holocene. Terrestrial paleosol sequences in the Croatian coastal karst regions are often incomplete due to erosion or non-deposition. Therefore, accumulation of lake and marine sediments offer complete and well-dated archives spanning through most of the Holocene. Part of the karstified AdCP is drowned and its palaeo-dolines and depressions of variable size contain up to 900 m of well stratified sediments (Kvarnerić bay, N. Adriatic) as indicated by seismic data. This allows an insight to earlier periods of the Quaternary. Generally larger karst depressions lie between the islands at present day water depths from -40 m to -90 m. These geomorphological and sedimentological landscapes contain archives of climate change and have experienced repeated relative sea-level cycles during the Quaternary. Between the last interglacial (MIS 5.5, 125 kyr BP) and Holocene (10 kyr cal BP) periods the present submerged depressions of Kvarnerić bay (-80 to -90 m below present day sea level), Valun bay and Lošinjski kanal due to submerged sills at various sea depths and the amounts of fresh water feeding the basins during the glacial low-stand favored development of shallow glacial freshwater lakes. The ongoing LoLADRIA (Lost Lake Landscapes of the Eastern Adriatic Shelf) project is using 5–10 m long sediment cores collected from 17 sites (7 lacustrine and 12 marine) along eastern Adriatic coast. These sediments allowed multiproxy reconstructions of the Holocene millennial- and centennial-scale environmental change. A landscape reconstruction of selected sites, based on high resolution geophysical methods, allowed insight into the preserved changes of marine sediments, submerged landscapes and the morphology of paleo-lakes in Lošinjski kanal, Kvarnerić, Novigradsko more and Karinsko

more, Pirovački zaljev and Koločepski kanal. The thickness of paleo-lake sediments varies from 2 m in Karinsko to more than 10 m in Lošinjski kanal. Details of environmental change are extracted by integrating mineralogy, lithostratigraphy, biostratigraphy (pollen, foraminifers, ostracods, tephrostratigraphy and chemical stratigraphy, with well-defined ^{14}C AMS radiocarbon chronologies. Most of the present day lakes along eastern Adriatic coast formed during the early Holocene (Bokanjačko blato, Vransko jezero near Biograd, Veliko jezero-Mljet). Vransko jezero on the Island of Cres survived from the Pleistocene as probably did Lake Crniševo (Baćina lakes). The LGM lakes of Lošinjski kanal and Valun bay were flooded at onset of the Holocene, while the Pleistocene lake in Pirovac bay was flooded by the sea 8 ky cal BP and Veliko jezero on Mljet Island at 3 ky cal BP. The Holocene lakes of Čepić polje, Bokanjačko blato, Nadinsko blato, Vrgoračko polje and most of the lakes of the Neretva river delta ceased to exist during the early 20th century due to human intervention to gain agricultural lands.

This work is supported by Croatian Science Fund Project LoLADRIA (Project no. 9419) and the EMODnet Geology II project funded by EC DG Mare.

Qualitative composition of the leeches (Annelida: Hirudinea) of Prespa Lake – Republic of Macedonia *P*

Smiljkov, S.[1], Ilieska, R.[1], Zikov, M.[2], Gusheski, D.[1], Nakova, S.[1]

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[2]Institute of Geography, Faculty of Natural Science and Mathemathics, 1000 Skopje, R. Macedonia

From our research of the representatives of the class Hirudinea (leeches) in Prespa Lake, were found 11 species from 4 different families.

Dominant family is Glossiphonidae, who was represented by the following species: *Glossiphonia complanata*, *G. concolor*, *Alboglossiphonia heteroclite*, *Helobdela stagnalis*, *Hemiclepsis marginata*, *Haementeria costata*, then comes family Erpobdellidae with the representatives *Erpobdella octoculata*, *Dina lineata* and *Dina* sp., and the families Haemopidae and Hirudidae, each represented by one species, *Haemopis sanguisuga* and *Hirudo medicinalis*, respectively. Most representatives of the fauna of the leeches are found in the littoral zone, and least representatives are found in profundal zone.

Unlike Prespa Lake, in the Ohrid Lake biodiversity of fauna of the leeches is far greater, namely there are 24 described species, of which 11 species are endemic, and the rest are cosmopolite.

Shape variation in Neotropical *Cytheridella* using semilandmarks-based geometric morphometrics: a methodological approach

Wrozyna, C.[1], Neubauer, T.A.[2], Meyer, J.[1], Piller, W.E.[1]

[1]University of Graz, Institute of Earth Sciences, NAWI Graz, Heinrichstraße 26, 8010 Graz, Austria
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Non-marine ostracods are a diverse group of microcrustaceans which occur in a wide range of aquatic habitats. Some morphological criteria (e.g., size, shape) of ostracods reflect the environment at the time the ostracod was calcifying its carapace. The type and amount of phenotypic variability can, thus, provide valuable information with regard to relationships between populations of a species. There is, however, a conspicuous deficit on studies dealing with systematic investigations on intraspecific morpho-

logical variability (of soft and hard parts) within and between populations.

To overcome the problem of addressing only a part of the morphological information, we applied morphometric analyses to ostracod valves. To test the applicability of geometric morphometrics using a combination of landmarks and semilandmarks for ostracods, we investigated shape variation among recent and fossil populations of the genus *Cytheridella* Daday, 1905. With this study, we aim to investigate the species' intraspecific morphological variability on a supra-regional scale, comparing living populations from Florida, Yucatán, Colombia and Brazil collected during 2009 and 2015. We performed Generalized least-squares Procrustes Analysis including Relative Warps analysis based on 8 traditional landmarks and 60 semilandmarks defining the valve outline. In order to exploit as much morphological information as possible, we used left and right valves from adults and instars, including stages A-1 to A-4. In total, 508 valves were used for the analyses (247 right valves, 261 left valves).

The analyses show that the primary pattern in shape variation is ontogenetic allometry, supporting a clear separation of adults and juveniles. Juveniles are not aligned according to instars. Insufficient differentiation of sexes is caused by females with less developed brood pouches. Disentangling size- and non-size-depending shape changes reveals regional differences between populations of the species *C. ilosvayi* Daday, 1905 and supports its taxonomic distinction from a fossil relative (*C. danielopoli* Purper, 1974). The regional morphological differences of *C. ilosvayi* indicate genetic divergence and may suggest taxonomic differentiation.

The change in the elevation of the Bosporus sill during the last deglaciation and its role in the delay of the early Holocene marine transgression of the Black Sea-Lake

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Evidence of a 95-mbsl paleo-shoreline on all of the Black Sea margins is coincident with persistent outflow through the Bosporus to the Marmara Sea-Lake when the Black Sea-Lake was at this level during the glacial and deglacial periods. The positive hydrological balance of precipitation and riverine inflow over evaporation kept both of the lakes fresh and outflowing at the elevation of this paleoshoreline, which was well above the global sea level during the glacial and early deglacial periods. Yet, the delayed entry of Mediterranean water into the Black Sea-Lake in the early Holocene indicates that the threshold depth of the Bosphorus was much shallower at that time, sitting at 35 mbsl.

Reflection profiles, cores, and geochemical measurements in the form of ^{14}C, $\delta^{18}O$, $\delta^{13}C$, and $^{87}Sr/^{86}Sr$ from all of the Black Sea shelves are brought together here support a proposed resolution to this apparent inconsistency in the form of a dynamic sill.

During the glacial period encompassing Marine Isotope Stages (MIS) 3 and 2, erosive outflow lowered the sill to its bedrock minimum such that the strong freshwater throughflow kept both the Black Sea-Lake and Marmara Sea-Lake fresh. The onset of warm and dry conditions during the deglacial Bølling/Allerød interval led to a lake-wide regression, a phenomenon that exposed the sill sub-aerially and allowed loose sediment to fill the sill to a much shallower depth. This shallower sill prevented inflow of water from the Mediterranean until the early Holocene, several thousand years

later after the entry of Mediterranean water into the Sea of Marmara. It is likely that the phenomenon of a dynamic sill is not unique to the most recent deglaciation but also characterized the MIS 6 to MIS 5 deglacial transition, and may be an integral feature of the Black Sea and its variable connection to the global ocean. This presentation features a unique interplay between lacustrine and terrestrial environments that should be explored in other paleoenvironmental systems.

SESSION B. PALEOBIOLOGY

KEYNOTE

Documenting mollusc biodiversity rise and demise in long-lived lakes: a combined geo-biological approach

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Long-lived lakes are laboratories and archives of evolution (Martens, 1997). Their (semi-) isolated position makes them model systems to study driving processes behind speciation and extinction and to relatively easily identify immigrant species and track their role in turnover. The biodiversity development in two long-lived lake systems, Miocene Lake Pebas in western Amazonia and the Quaternary Pontocaspian Lake System comprising the Black Sea Basin (BSB) and Caspian Sea Basin (CSB) are reviewed.

In Miocene Lake Pebas origination appears to have been a relatively gradual process over millions of years with only few immigrant species playing minor roles (Wesselingh & Salo, 2006). A diversity drop has been linked to increased marine influence and the fauna went almost entirely extinct with the transition of the lake system to a fluvio-estuarine system c. 10 Ma (Hoorn et al., 2010). Drivers behind speciation include ecological specialisation enabling the occupation of dysoxic habitats and very high predation pressure (Salas-Gizmondi et al., 2015).

The Pontocaspian system has undergone very rapid successions of speciation and extinctions in its two million year's history (e.g. Nevesskaja, 2007). The two main basins (BSB, CSB) experienced periods of isolation and connection (Badertscher et al., 2011) and during the Middle-Late Pleistocene Pontocaspian biota in the BSB were pushed into marginal coastal areas during marine ingressions at interglacials. Speciation bursts are poorly understood but likely followed major extinctions. The latter can be correlated to interglacial marine intervals in the BSB and to major deep regressions in the CSB (Yanina, 2012). Furthermore, migration of Pontocaspian biota between the basins during episodic connections also shaped their faunal composition. In the 20th century the Pontocaspian biota suffered a severe biodiversity crisis (Kosarev & Jablonskaya, 1994; Grigorovich et

al., 2003). Although difficult to prove extinction it appears that many of the c. 160 endemic species in the Caspian Sea have been wiped out, apparently as a result of a few immigrant species only. Pontocaspian coastal habitats in the BSB suffer degradation (Popa et al., 2009) yet we present a case from the Lake Razim complex in Romania where habitats expanded due to human interference.

In this review we will show an interactive effort to study and understand anthropogenic turnover and to make a distinction from natural background processes. We document the case of Lake Razim and also will elaborate on the search of possible refuges in the Caspian Sea.

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Diversity of Lake Pannon molluscs in the Transylvanian Basin (Romania) *P*

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During the Late Miocene, Lake Pannon covered most of the Pannonian Basin System, including the Transylvanian Basin. The estimated age of the Pannonian sediments in this basin is between 11.6 and 9.5 Ma. The younger deposits were eroded due to the tectonic inversion and intense erosion, therefore the thickness of the Pannonian sequence is only 300 metres. Today, these sediments occur in an isolated but more or less contiguous area in the central and southern part of the basin. The position of the original palaeogeographic connection between the Pannonian and Transylvanian Basins is still a matter of debate; it was probably through the Sălaj area (north) and/or the Mureş Valley (south).

No detailed and comprehensive treatise has ever been published on the Pannonian molluscs of this basin, therefore our first and most important objective is the taxonomic revision of the fauna. We collected molluscs from 12 localities (Agârbiciu, Bodogaia, Chibed, Cristuru Secuiesc, Gârbova de Jos, Gârbovița, Gușterița, Lopadea Veche, Mihalț, Oarba de Mureș, Tău and Vingard), and compare them with the published data. We investigate the collections of the Hungarian Natural History Museum, Budapest (5 localities: Apoldu de Sus, Crișeni, Lopadea Veche, Săcădate and Sâncrai-Dealu) and that of the Geological and Geophysical Institute of Hungary (19 localities: Bucerdea Grânoasă, Cetea, Cunța, Deda, Galda de Jos, Gârbova de Sus, Gârbovița, Geoagiu de Sus, Jidvei, Miercurea Sibiului, Nocrich, Ruși, Sângeorgiu de Mureș, Șilea Nirajului, Șoimușu Mic, Șona, Țapu,

Tătârlaua and Vurpăr). Altogether the fauna of 34 localities was determined so far.

Although the literature and the museum labels display a large number of species names, the real number of forms in the Pannonian of the Transylvanian Basin is rather limited. So far we have identified 27 species in the newly collected and revised materials. The most species-rich fauna, that of Gușterița, included only 14 species. The reason of this low diversity is two-fold. First, the littoral deposits of Lake Pannon, together with their probably highly diverse fossil fauna, have mostly been eroded since the Late Miocene as a consequence of basin inversion. Only 4 of our 34 localities (Geoagiu de Sus, Nocrich, Sâncrai-Dealu and Vingard) contain unanimously autochthonous littoral mollusc fauna (with dreissenids, such as *Congeria partschi* and *C. ramphophora*, unioniids, such as *Unio mihanovici*, and grazing snails, such as *Melanopsis bouei, M. fossilis, M. magna, M. pygmaea* and *M. vindobonensis*). The second reason is that mollusc diversity sharply declined with depth in Lake Pannon, and the sublittoral and profundal sediments preserved low-diversity mollusc assemblages. The characteristic forms of these faunas include thin-shelled cardiids (*Paradacna lenzi*, *P. syrmiense*, "*Lymnocardium*" *praeponticum* and "*L.*" *undatum*), dreissenids (*Congeria banatica*), pulmonate snails, such as planorbids (*Gyraulus praeponticus, G. tenuistriatus, G. vrapceanus, Orygoceras brusinai* and *O. levis*) and lymnaeids (*Undulotheca pancici, U. rotundata, Velutinopsis nobilis* and *V. velutina*).

With further collection and investigation of the fossil material, sedimentological field studies, and revision of other fossil collections, our objective is to get better acquainted with the low-diversity mollusc fauna of the Early Pannonian, to explore the palaeogeographical relations, and to develop the biostratigraphic resolution of the Early Pannonian sediments.

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Quaternary Pontocaspian lake phases in the Marmara Sea Basin

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The Marmara Sea Basin is the doorstep between the Black Sea and Aegean-Mediterranean basins. In the Quaternary conditions in the Marmara Sea Basin switched repeatedly from marine to isolated lacustrine to Pontocaspian lacustrine settings. The Quaternary record in the Marmara Sea is very fragmented, yet improved age estimates of fossiliferous deposits improve very much our understanding of the lake phases in the region and their potential for understanding biotic evolution in Pontocaspian basins. Here I present Middle and Late Pleistocene intervals and faunas, present an improved stratigraphic framework and show their significance for the regional evolution of lake basins and faunas. The intervals contain diverse Middle Pleistocene (Chaudian: Gelibolu in the west and Early Khzarian: Iznik Lake Basin in the East) and Late Pleistocene (Surozhian–Neoeuxinian) localities (Iznik Lake Basin, Izmit Bay area and core samples from the southern Marmara Basin/ Gemlik Bay area). Pontocaspian overflow and marine higstands are matched to the stratigraphic scheme developed by Bardetscher et al. (2011).

Badertscher, S., Fleitmann, D., Cheng, H., Edwards, R.L., Göktürk, O.M., Zumbühl, A., Leuenberger, M., Tüysüz, O. 2011. Pleistocene water intrusions from the Mediterranean and Caspian seas into the Black Sea. Nature Geoscience 4: 236–239.

A Late Pleistocene Pontocaspian refuge in the south of Turkey? *P*

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A Late Pleistocene mollusc fauna from the Karapinar Basin (Anatolia, Turkey) contains three Lymnocardiine species. Two of the species are described as new. Radiocarbon datings imply an age of approximately 35–43 ka. We speculate that the Karapinar fauna is a geological short-lived record of Pontocaspian biota far away from their main Black Sea – Caspian Sea centres of origin and that avian dispersal is the only realistic way to explain their occurrence. This rises also the possibility that southern Anatolian lakes may have served as Pontocaspian refugia.

Büyükmeriç, Y. & Wesselingh, F.P. 2016 (in press). New cockles (Bivalvia: Cardiidae: Lymnocardiinae) from Late Pleistocene Lake Karapınar (Turkey): discovery of a Pontocaspian refuge? Quaternary International Special Volume.

Palaeoecology of Pannonian ostracod faunas from Pécs-Danitzpuszta in S Hungary: a preliminary study *P*

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Present study is focused on Lower Pannonian marly series of Lake Pannon exposed in a sand pit in Pécs-Danitzpuszta. The investigated layers consist of calcareous marls, claymarls and calcareous sands belonging to the the Endrőd Marl Formation. They belong to the *Lymnocardium schedelianum* mollusc biozone, with an age of ~11–10 Ma. The sequence is heavily tilted, nearly vertical and is conformably overlain by Pannonian sand layers famous for their unique Middle to Late Miocene reworked terrestrial and marine vertebrate remains. Well preserved, relatively diverse benthic ostracod faunas were recovered from the studied 23 samples. Twenty-one euryhaline benthic ostracod taxa could be identified suggesting a limno-brackish environment with low-energy conditions based on their morphological and ecological characteristics. The ostracod assemblages of the older layers in the studied sequence are dominated by several species of *Candona* s.l. beside *Cyprideis*, *Cypria* and *Loxoconcha* suggesting a mio- to mesohaline (3–9 ‰), littoral/shallow sublittoral (with ca. 10–15 m water depths) environment. Towards the younger strata the ornamented specimens of the genus *Cyprideis* become dominant beside *Herpetocyprella*, *Hemicytheria* and *Amplocypris* indicating meso- to pliohaline (5–16 ‰) sublittoral (with 10–80 m water depths) conditions. Based on the biostratigraphical interpretation of the ostracod faunas, the studied section belongs to the *Hemicytheria tenuistriata* Zone of Lower Pannonian (Krstić, 1985). In summary, the sedimentological variability of the sequence and the palaeoecological evaluation of the ostracod faunas indicate a nearshore position of the section during the early Late Miocene and a slight increase in salinity and in water depth towards the open lacustrine depositional environment in this subbasin of Lake Pannon.

The research is supported by the Hantken Foundation and by the Hungarian National Research, Development and Innovation Office (NKFIH – 116618 and PD 104937).

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Latonia gigantea (Anura, Alytidae) from the Middle Miocene of Lake Vračević (Serbia) [P]

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The Middle Miocene sediments of Vračević yielded rich fossil vertebrates association. The herpetological remains at this site were partially described in an earlier paper (Jovanović & Đurić, 2005). Presence of frog *Latonia* at Vračević was the first record in Serbia. This genus of large frogs belongs to a family Alytidae (Discoglossinae). Until recently Latonia was considered to be an extinct genus present from late Oligocene to Pleistocene. (Biton et al. 2013) believe that the rediscovered hula painted frog (Israel, Hula Valley) is actually a living fossil named *Latonia nigriventer*.

The fossil remains include disarticulated and highly fragmented jaw bones and axial skeleton. The poor state of preservation made identification very difficult. The maxilla fragments lack secondary ornamentation which as *L. ragei*. However ornamentation may be absent in younger individuals of *L. gigantea* (Roček, 1994). Due to the fact that remains have the features of a smaller individual, they were identified as *Latonia* cf. *gigantea*.

Latonia is a representative of periaquatic Amphibians (Venczel & Stiuca, 2008). It is found in humid habitats near water bodies, as is the case with the species *L. nigriventer*. Presence of this species in sediments of Vračević leads to conclusion that during the Middle Miocene (Sarmatian) this locality was characterized by lacustrine-swampy paleohabitat.

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A minute ostracod (Crustacea) from the Miocene Solimões Formation (western Amazonia, Brazil) – Evidence for marine incursions?

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A huge wetland (the 'Pebas system'; Hoorn et al., 2010) covered western Amazonia during the Miocene, hosting a highly diverse and endemic aquatic fauna (e.g., molluscs, ostracods). One of the most contentious issues concerns the existence, potential pathways and effects of marine incursions on this ecosystem. Palaeontological evidences (body fossils) are still rare. The finding of a presumably marine ostracod species (*Pellucistoma curupira* Gross, Ramos & Piller, 2015) in the upper middle Miocene Solimões Formation initiated a taxonomic, ecological and biogeographic review of the genus *Pellucisto-*

ma. We demonstrated that this basically marine (sublittoral, euhaline), subtropical-tropical taxon is biogeographically confined to the Americas. The biogeographic distribution of *Pellucistoma* largely depends on geographic, thermal and osmotic barriers (e.g., land bridges, deep and/or cold waters, sea currents, salinity). We assume an Oligocene/early Miocene, Caribbean origin for *Pellucistoma* and outline the dispersal of hitherto known species up to the Holocene. P. curupira is dwarfed in comparison to all other species of this genus and extremely thin-shelled. This is probably related to poorly oxygenated waters and, in particular, to strongly reduced salinity. The associated ostracod fauna (dominated by the eurypotent *Cyprideis* and a few, also stunted ostracods of possibly marine ancestry) supports this claim. Geochemical analyses ($\delta^{18}O$, $\delta^{13}C$) on ostracod valves furnished constantly very light values, indicative for a freshwater setting. These observations point to a successful adaptation of *P. curupira* to freshwater conditions and therefore do not signify the presence of marine waters. *P. curupira* shows closest affinities to Caribbean species. We hypothesise that *Pellucistoma* reached northern South America (Llanos Basin) during marine incursions in the early Miocene. While larger animals of marine origin (e.g., fishes, dolphins, manatees) migrated actively into the Pebas wetland via fluvial connections, small biota (e.g., *P. curupira*) were phoretically freighted and developed freshwater tolerance over long time scales.

Gross, M., Ramos, M.I.F. & Piller, W.E. 2015. A minute ostracod (Crustacea: Cytheromatidae) from the Miocene Solimões Formation (western Amazonia, Brazil) – Evidence for marine incursions? Journal of Systematic Palaeontology, DOI: 10.1080/14772019.2015.1078850.

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Lacustrine Karpatian to lowermost Badenian ostracods and palynomorphs from Sjeničak section (Croatia) *P*

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In Croatia the pre-Badenian lacustrine, alluvial, fluvial and deltaic deposits occur in the Sava and Drava depressions, in their sub-depressions, as well as on the inselbergs between them. The Sjeničak section is located in the Karlovac sub-depression which, according to Mandic et al. (2012) could represent a zone independent from the Sava depression. It is related to the intra-mountainous basin of the Dinaride Lake System.

The present work is a continuation of an earlier study of the Sjeničak section (Mandic et al., 2012). According to Mandic et al. (2012) lacustrine deposits from the Karlovac sub-depression are characterized by abundant dreissenid bivalve accumulations of the Illyrian Bioprovince type. Weighted mean Ar/Ar age for the Sjeničak ash is 16.00 ± 0.09 Ma (De Leeuw et al., 2012; Mandic et al., 2012). This age indicate that the Southern Pannonian Basin continental phase lasted at least 2 Ma (Mandic et al., 2012) and that it coincides with the deposition of lacustrine sediments with similar fauna in the more interior parts of the Dinarides.

For the present study two samples were analyzed from the Sjeničak section; a clayey

sediment sample (Sjeničak 1) and a sandy sediment sample (Sjeničak 2), located just below and above the dated volcanic ash layer.

The dominant, rich and exceptionally preserved ostracod fauna was separated from the clay sediment sample Sjeničak 1. The most common are ostracod species *Dinarocythere* cf. *reticulata* Krstić & Sokač, *Sarscypridopsis* cf. *aculeata* (Costa) and *Pontoniella* sp. Ostracod species *Herpetocypris* cf. *chevreuxi* (Sars) and *Darwinula stevensoni* (Brady & Robertson) as accompanying, are less abundant taxa. Species *Dinarocythere* cf. *reticulata* and *Sarscypridopsis* cf. *aculeata* recognised in the sample, are recorded for the first time in Miocene deposits of Croatia. Furthermore, *Sarscypridopsis* cf. *aculeata* recognised here is recorded for the first time in Miocene lacustrine deposits of Europe. The sample below the volcanic ash layer is also characterized by a very diverse palynomorph assemblage dominated by conifer pollen (*Pinus, Cathaya*), riparian trees (*Carya*) and thermophilous fern spores (*Echinatisporis, Verrucatosporites, Cingulisporis, Leiotriletes*) as well as freshwater algae (*Spirogyra, Pediastrum, Botryococcus*). Along with ostracod and palynomorphs some limonitic shell of gastropods, few oogonies of Characeae and rhizolits were determined.

In the sample above the volcanic ash layer thermophilous fern spores decrease, while pollen of riparian trees (*Carya, Alnus*) and conifer (*Pinus, Cathaya, Picea, Podocarpus*) increase. Ostracode fauana of sample Sjeničak 2 slightly differ from the previous sample. Ostracod carapaces are poorly preserved and wrapped with the sediments, broken and were determined on the genus level. Ostracods from sample Sjeničak 2 belongs to genera *Sarscypridopsis*, *Pontoniella* and *Herpetocypris*.

Ostracod assemblages from sample Sjeničak 1 differ from all known ostracod assemblages of the same age in a wider area of Croatia. Endemic genus *Dinarocythere* with four different species are known from the lacustrine Middle Miocene of the inner and central Dinaric belt (Krstić, 1987). Findings of the endemic genus *Dinarocythere* can be correlated to the locality Sjeničak with the locality Žegar near Bihać in Bosnia and with other different localites in Serbia (Miocene Serbian lake) where this genus has been found (Krstić, 1987).

The composition of the ostracod fauna and the dominance of well-preserved saltwater ostracods like endemic species *Dinarocythere* cf. *reticulata* which lived in calm environment (Krstić, 1987) and *Sarscypridopsis* cf. *aculeata* cosmopolitan species widely distributed along the sea costs of Europe which prefer a slightly brackish water (Meisch, 2000), imply to relatively saline water bodies (mesohaline) in a close distance to the Badenian sea with potential influence of the sea water by sea spray and/or through the aquifer system.

Thermophilous fern (*Echinatisporis, Verrucatosporites, Cingulisporis, Leiotriletes*) and pollen (*Platycarya, Myrica*) indicate a subtropical climate and Karpatian–Lower Badenian age of the lower sample, and a less humid and more warm-temperate climate, for the upper sample.

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The first paleontological records of dreissenid bivalve larvae in Sarmatian of Serbia [P]

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Representatives of Neogene dreissenids, like many other bivalves, pass through several stages during their ontogenetic development. Due to their economic importance, there is an increasing interest in studying the modern invasive species. Special field guide (Conn et al., 1993) was prepared for determination of certain modern representatives of family Dreissenidae (*Mytilopsis leucophaeata* and *Dreissena* spp.). However, identification of larvae in various bivalve genera, both recent and fossil, is much more difficult than with gastropods.

Very few records of well-preserved fossil bivalve larvae have been published so far. Location of one of these rare records is in the territory of village Jelovik, within the Kovačevac stream south of Mt Bukulja (Serbia). Larval shells were preserved in clayey silt determined as being of Lower Sarmatian age (Krstić et al., 2011). The collected material includes more than 50 well-preserved, densely packed solid larval shells at the surface area less than 1 cm^2, as well as several individual shells widely spaced around the sediment. In addition to bivalve larvae there are also several damaged juvenile specimens and deposited shells of adult dreissenids. The shells of larval forms are thin and relatively solid, almost circular in shape, pointed with a pronounced umbo, indicating the postlarval phase of bivalve development when the foot is developed. In juvenile specimens shell is elongated and slightly pointed, and the umbo is well-developed.

Shells of both larvae and juvenile stages recorded at Jelovik may be significant for studies of development of Neogene dreissenids, particularly regarding the Sarmatian dreissenid fauna of bivalves in central Paratethys. In the previous studies the family Dreissenidae was represented with the single genus *Mytilopsis*, so it would be logical to conclude that the larvae are also belonging to this genus. However, presence of several forms of adult individuals and the newest data on older lacustrine fauna of the Dinaric system of lakes (Neubauer et al., 2016) indicate a possibility that other genera of bivalves from family Dreissenidae might have existed at the territory of Jelovik during the early Sarmatian.

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Mollusks and ectothermic vertebrates from the Middle Miocene (Sarmatian) Lake Vračević (Serbia)

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While there is a wealth of data on marine Sarmatian fauna of Serbia, life in lacustrine and terrestrial environments has remained almost unstudied. This paper presents the newest results of studies on Middle Miocene (Sarmatian) fauna of mollusks and ectothermic vertebrates

Lake Vračević. This site is situated close to Belgrade, at the southern periphery of Pannonian Basin. The fossil material was collected from clay and sand-based sediments about 2 m thick. According to micromammalian fauna and the previous studies (Marković, 2003; Jovanović & Đurić, 2005), the assumed age of sediments is late Middle Miocene (MN 7+8). Kovalenko (2004) and Prysjaznjuk & Rudjuk (2005) used a smaller number of described mollusk species to assign a somewhat earlier age (early Sarmatian on boundary with Badenian of the Ukraine) to these sediments. According to borehole data (Filipović et al., 1978), the lacustrine sediments show lateral alternation with brackish sediments including the Upper Sarmatian bivalve from Paratethys, *Sarmatimactra vitaliana eichwaldi*.

Mollusks are important for studies of ancient lakes that also contain numerous remains of various vertebrates in form of individual parts of skeleton, and small lake Vračević matches this description. Therefore the importance of stratigraphic position of continental mollusks is increasingly recognized (Harzhauser et al., 2008). Rich mollusk fauna shows a certain degree of endemism. Small gastropods are dominant over the bivalves. Larger gastropods are represented only by shell fragments. This paper includes first records of freshwater *Bithynia* as well as terrestrial gastropods *Derocer-as, Vallonia, Carychium, Vertigo, Strobilops, Acanthinula* etc. Very common species include *Carychium* sandbergeri and bivalve *Pisidium*. Opercula of *Bithynia* and *Pomatias* are rare as well as Characea gyrogonites. Collected material also includes numerous ostracods, pincers of freshwater decapod (*Potamon*) crustaceans and insect remains.

Although highly fragmented, remains of ectothermic vertebrates show high taxonomic diversity. Fish remains are most common. One fish scale about 1 mm in diameter was identified as belonging to a small member of Gobiidae. The otoliths belong to genera *Aphanolebi-as* (Cyprinodontiformes) and *Gobius* (Gobiidae). Anura are represented by *Latonia* cf. *gigantea*, *Rana* sp., *Pelobates* sp., *Bufotes* sp., while identified Urodela include *Salamandra* cf. *sansani-ensis* and *Lissotriton* cf. *vulgaris*. Among the remains of Squamata the most abundant are osteoderms of *Pseudopus* sp. Snake vertebrae belong to small Colubridae and Viperidae, with only one identified vertebra of Scolecophidia indet.

Alternation of different sediment types and various life and deposition environments enable reconstruction of lake development and processes influencing the alternations, as well as the diversity of life in region of Vračević during the Middle Miocene (Sarmatian). The terrestrial mollusks and ectothermic vertebrates are excellent indicators of paleoenvironments, enabling the researchers to properly reconstruct life on dry land at the time when Paratethys started to retreat from present-day Serbia.

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Predictors of shell size in long-lived lake gastropods

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This study aims at investigating shell size variation among gastropod faunas of fossil and recent long-lived European lakes and discussing potential underlying processes. Based on a dataset of 1412 species of lacustrine gastropods from 23 Miocene to Recent long-lived lakes, we assessed differences in shell size in terms of characteristics of the faunas (i.e., species richness, degree of endemism, differences in family composition) and the lakes (i.e., surface area, latitude and longitude of lake centroid, distance to closest neighboring lake) using multiple and linear regression models. Because of a strong species-area relationship, we applied a resampling approach to determine whether any observed correlation is driven by that relationship.

The regression models indicated size range expansion rather than unidirectional increase or decrease as the dominant pattern of size evolution. The multiple regression models for size range and maximum and minimum size were statistically significant, while the model with mean size was not. Individual contributions and linear regressions indicated species richness and lake surface area as best predictors for size changes. Resampling analysis revealed no significant effects of species richness on the observed patterns. The correlations are comparable across families of different size classes, suggesting a general pattern.

Although the most outstanding and attractive examples for size evolution in lacustrine gastropods derive from lakes with extensive durations, shell size appears to be independent of the duration of the lake as well as longevity of a species. Consequently, the analogue of long-lived lakes as “evolutionary islands” does not hold for developments of shell size because different sets of parameters predict size changes.

The biota of an Arctic Eocene maar lake during a greenhouse environment with an emphasis on the sponges

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The Giraffe fossil locality in Northern Canada is contained within a crater formed during emplacement of a kimberlite diatreme that intruded the Slave Craton of the Canadian Shield approximately 47.8 ± 1.4 Ma. The crater filled with an organic sediment sequence and was later capped with Neogene glacial deposits. Over 60 m of lacustrine sediments (laminated shales and mudstones) comprise the lower maar facies, which is succeeded by approximately 40 m of terrestrial sediments that include significant amounts of *Metasequoia* foliage and wood. The transition between lacustrine and terrestrial sedimentation occurred approximately 38 Ma, implying that the entire lake sequence is middle Eocene (Lutetian Stage) in age. The lake sediments from the Giraffe locality have yielded a rich assemblage of siliceous microfossils, including diatoms (Bacillariophyceae), chrysophytes (Chrysophyceae and Synurophyceae), euglyphids (Euglyphidae, Rhizaria) and spongillids.

The waterbody contained within the crater began as a shallow water pond situated at the base of a relatively deep crater. This aquatic phase lasted for thousands of years, slowly infilling part of the crater. Then, over a short period of time, the crater filled to form a deep lake as evidenced by sudden appearances of large concentrations of planktonic diatoms and planktonic colonial chrysophytes, coupled with a significant decline in abundances of euglyphids and sponges. Over time, the deep lake progressively infilled and once again became a shallow pond or wetland. Thermal and tectonic stability of the locality post kimberlite emplacement has resulted in excellent preservation of both siliceous and non-siliceous fossils.

The sponge microfossil record from the Giraffe locality comprises a wide array of loose spicules including numerous megascleres, gemmuloscleres (spicules forming an armor of the resting bodies and including both birotules and non-birotules), and microscleres. At least 10 distinct taxa can be identified based on spicule morphology, the most common belonging to *Ephydatia*, but representatives of *Racekiella, Heteromeyenia, Dosila, Radiospongilla, Spongilla, Paleospongilla, Hosuayella* and *Trochospongilla* are also present. A new species, *Potamophlois canadensis*, belonging to the warm water freshwater sponge family Potamolepiidae, was described from these sediments. Another species belongs unambiguously to the genus *Ephydatia* (family Spongillidae) and is morphologically nearly identical with the living species *E. facunda*. The latter species is known from Brazil and Argentina and is characteristic of a warm climate. Taking additionally into account data about some diatoms and synurophytes, a warm to tropical climate is postulated in Northern Canada during Middle Eocene. Lastly, many of the fossil taxa representing the euglyphid thecamoebans, synurophytes and sponges display morphologies similar to modern congeners and represent examples of evolutionary stasis.

New data on Karpatian-Badenian freshwater and brackish lacustrine sediments in the Mecsek Mts., Hungary *P*

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After the Early Miocene fluvial, marsh and partly lacustrine sedimentation, the "*Congeria*-bearing unit" and the „fish-scale-bearing claymarl" (Pécsvárad Limestone and Komló Claymarl Members of the Budafa Fm.) in SW Hungary are considered to represent transition from brackish water to fully marine conditions. Due to the lack of marine fossils the age of the *Congeria* unit is uncertain, latest Karpatian or Early Badenian; part of the Komló Claymarl contains rare forams indicating earliest Badenian (NN4). Sedimentological, stratigraphical and paleontological investigations are conducted recently in order to gain more information on the age and environmental conditions of these sediments; some preliminary results are presented here.

The *Congeria*-bearing unit usually overlies basement rocks. However, separate *Congeria* beds occur in higher parts of the succession as well, both within the Komló Claymarl and the Budafa Sandstone Member (the 3rd, upper member of the Budafa Fm.). Because of the complete lack of marine fauna like foraminifers, they are usually considered to represent brackish conditions.

Congerias occur both as moulds and as shells in several lithofacies:

– Thick bioclastic limestone beds composed of mostly double *Congeria* valves and sporadic gastropods, with or without little sandy matrix. They occur between sand layers. They may represent in situ *Congeria* colonies,

though the indistinct layering may also refer to agitated shoreface waters with redeposited shells. Besides the "*Congeria* unit", this lithotype occurs interbedded into the fish-scale claymarl and in the Budafa Sandstone as well.

– Bioclastic – sometimes sandy – limestone composed of single *Congeria* valves and sporadic gastropods, both moulds and shells, with shells oriented parallel with bedding. These coquinas indicate agitated shoreface waters and can be interpreted as storm beds. They occur as interbeds in coarse littoral conglomerates.

– Coarse, monomictic littoral conglomerates, with sporadic single *Congeria* valves among the clasts. These are high-energy wave-worked sediments. They usually directly overly basement rocks.

Congeria assemblages are typically monospecific, with *Congeria* (now *Trigonitaxis*) *boeckhi* and less frequent *Bulimus*(?) (now *Ferebithynia*) *vadaszi*. The occurrence of a single bivalve species, *Trigonitaxis boeckhi* in rock-forming quantities, together with *Ferebithynia* sp., occurring together with *Theodoxus* in freshwater sediments in NW Hungary (Bakony Mts.), may indicate quasi-freshwater environment. The ostracod assemblage dominated by *Cyprinotus*(?) sp., *Cypria* sp. and *Candona* sp. also indicates freshwater conditions; double valves refer to rapid sedimentation.

Into the Komló Claymarl fairly different sediments are classified: massive or laminated claymarls, also sands, with high organic content, often with macroflora. They were interpreted partly as lagoonal, partly offshore, while in certain sub-basins as fluvial. The formation contains interbeds of the Tar Dacite Tuff Fm. („middle rhyolite tuff"). In connection with efforts to improve the dating of both the tuff layers and the sediments, parallel sampling of tuffs and host sediments is being carried out.

The already processed few samples were treated with acetic acid. They contained no age indicator fossils and refer to fresh to brackish water. They include a few sponge spicules, fish bone and scale fragments and ostracod remnants and no forams.

Based on own and literature data, it seems that foraminifers indicating at least brackish marine conditions preferentially occur at locations where there are no *Congeria* beds, neither below the claymarl nor within it. Although not exclusively, *Congeria* beds occur within the distribution area of the Komló Claymarl in more marginal positions, often with more coarse-grained (silty-sandy) sedimentation. This may indicate intense freshwater inflow, perhaps in a low-salinity lagoon, and/or stratification of the water in the basin. It also means that these marginal successions can only be dated indirectly, which needs very careful lateral correlation.

Pliocene freshwater paleolake Jradzor, Armenia: Preliminary data [P]

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The studied diatomite deposit is situates in the Yeranos mountainous range, Central Armenia, at the elevation of the 1920 masl. The diatomite deposit has thickness of about 8 m and lateral extension of ca. 150 m. The deposit is underlain by a bed of solid pyroclastic breccia. Nearly entire section contains pure and porous diatomite rock with extremely low clay and sand content. Due to this property the diatomite sediment is actively mined. In the lowermost part of the section two black sandstones are present in the diatomite, indicating erosion of the lake surrounding volcanic rocks and their fluvial transport. Overlying 7 m tick diatomite bed shows fine (red to yellow coloured) lamination. The bed is intercalated by the 2–10 cm tick

layers rich on clay and sand, indicating phases with terrestrial input during the lake development. The uppermost 60 cm of the diatomite is represented by grey-brown clayey diatomite and overlying grey-bluish sandstone. The diatomite is covered by conglomerate, showing sharp erosive contact with underlying beds. Laterally the upper bed is eroded and conglomerates lie directly on upper part of the 7 m thick diatomite pocket. The presence of the stratigraphic markers – pennatic diatoms *Cymbella elongata* Poretzky and *Pinnularia meisteri* f. *armenica* Poretzky in the diatom assemblage allows tentatively date the age of deposition back to the Pliocene.

Fossil diatom algae have excellent preservation. Overall, the diatom flora suggests that a freshwater lacustrine palaeobiotope was characterized by high productivity and eutrophic conditions during the deposition of diatomites. The common presence of epiphytic diatoms of the genera *Cymbella, Epithemia, Rhopalodia* and *Gomphonema* is clearly indicative of the presence of standing macrophyte vegetation along the littoral zone of the palaeolake. Presence of the mainly pure diatomite rock reflects low clastic input from the surrounding land. Laminated diatomites indicate probably a general absence of bioturbation in anoxic basin, seasonal variations. The presence of a permanent cover of littoral macrophytes is also testified by the abundant fossil remains of monocotyledons, as well as of the marsh frog *Pelophylax* cf. *ridibundus*, which is more pronounced in the upper layers of the deposit.

Beside botanical remains, the diatomite deposit provide remains of fishes (*Leuciscus* cf. *souffia*, *Leuciscus* sp., *Garra* sp., *Capoeta* sp.), an amphibian (*Pelophylax* cf. *ridibundus*), a reptile (Geoemydae indet.) and mammals (? *Hypolagus* sp., Rhinocerotidae indet.), allowing reconstruct the paleoenvironment of the lake during different staged of its development. The fishes are presented both complete and incomplete (fragments) skeletons. The (nearly) complete skeletons are found from the lower layers of the section in the central part of the deposit, whereas incomplete specimens are found from its distal part as well as from overlying layers. The taphonomy of the fish remains allow to conclude about their resident lacustrine populations in the lake, at least in earlier staged of the lake sedimentation. The resident lacustrine fish populations were energetically supported by the extremely abundant food availability within the palaeolacustrine system. The accumulation of skeletal remains likely occurred in the distal deep portions of the palaeolake where the preservation was favoured by the poorly oxygenated bottom conditions caused by the seasonal diatom blooms, as well as by their consequent high sedimentation rates.

Rodent assemblages from the early Miocene and Oligocene of Bosnia Herzegovina and Serbia

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Mammalian biostratigraphic correlation between the Oligocene and early Miocene of western Europe and Anatolia is hampered by a large area in between with almost no information on fossil mammals, only a few assemblages from Serbia and northern Greece are known. Fieldwork and research since 2003 in this area resulted in several small mammal assemblages, mainly of early Miocene age, and two Late Oligocene ones. The early Miocene and late Oligocene assemblages show similarities to both Anatolian and western European ones, indicating a transition area of mammalian fauna between the two areas.

Older small mammal assemblages from the Late Eocene/Early Oligocene sites have been discovered in south east Serbia in 2010–2014.

Preliminary identification of the rodents from these sites shows that these are quite diverse and contain a large number of new species. These Paleogene assemblages from Serbia are dominated by Muridae, which is in sharp contrast to the contemporary theridomyid-dominated ones from western Europe. Common members in many Eurasian faunas such as *Eucricetodon*, as well as members of Eomyidae, Sciuridae and Gliridae, are also absent in the the Late Eocene/Early Oligocene assemblages from Serbia. The presence of an array of new species suggests that we are dealing with hitherto unknown rodent associations that developed on a Dinaro/Balkanian micro-continent.

The peculiar composition of these Paleogene rodent associations hampers a straightforward correlation with successions from elsewhere. A few associations with a somewhat similar composition are known from the Lesser Caucasus and Baluchistan. The occurrence in Serbia of a representative of the Diatomyidae, a family that has so far been considered to be endemic to south east Asia, in the early Oligocene assemblages suggests that this family may have a different area of origin than previously assumed.

The new faunas are of great interest for a better understanding of the distribution and evolution of the Muridae around the “Grande Coupure” as well as for reconstructing the paleogeography of the Balkans.

SESSION C. STRATIGRAPHY

KEYNOTE

Dating the lake histories – integrated stratigraphy and correlation of isolated paleoenvironments

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The long-lived Dinaride Lake System (DLS) was a vast lacustrine environment covering an area of up to 75,000 square kilometer in today south-eastern Europe. It occupied multiple tectonic depressions within the Dinaride mountain chain and was located at a crucial geographic position between Central Paratethys and Mediterranean. While the richly preserved Neogene mollusks of the Dinaride basins provide an impressive example of mollusk radiation, the strictly endemic character of these mollusks inhibits straightforward biostratigraphic correlation with regions outside the DLS. Until recently, the age of these lacustrine deposits remained enigmatic. Good constraints can, however, be obtained using magnetostratigraphic, cyclostratigraphic and radiometric dating techniques. An absolute timescale and good correlations between the different Neogene basins provide better insight in the space-time evolution of the DLS, the timing and mechanism of basin formation, and the interpretation of mollusk speciation and radiation rates.

The conducted integrative research of the last decade has allowed us to determine a detailed chronology and paleogeographic setting for different DLS basins. Those results provided a completely new insight into the evolutionary history of a unique mollusk fauna originating from that fresh-water setting. The investigations were carried out in Croatia and Bosnia and Herzegovina, where corresponding lacustrine deposits crops out in tectonic depressions of the Dinaric Alps or on isolated hills of the southern Pannonian basin. Our integrated geophysical and geochemical measurements enabled the exact age calculations delimiting the Dinaride Lake System duration to the time interval between 17 and 13 Ma, i.e. during Early to Middle Miocene, concurrent with profound extension in the neighboring Pannonian Basin. Our paleomagnetic results further indicate that the Dinarides have not experienced any significant tectonic rotation since the late Oligocene.

Long-term Sedimentary Trends of Neogene Lake Systems of the Iberian Plate

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Internally drained basins are frequent in the Cenozoic history of the Iberian Plate. Their origin and evolution resulted in first order from a complex geodynamic context, related to the convergence of the major bounding plates of Africa and Eurasia, and the rifting and opening of the western Mediterranean Basin. Attempts to provide an integrated chronostratigraphic frame for all these disparate records have followed different approaches, including tectonosedimentary analysis, fossil vertebrate biostratigraphy, magnetostratigraphy and cyclostratigraphy. An outstandingly long sedimentary record is found in the Ebro Basin, where the combination of foreland flexure and uplift of bounding thrust-belts provided with the accommodation space for long-lived lacustrine systems since the late Eocene to middle-late Miocene. Sedimentation in the Ebro basin ended when fluvial drainage opened towards the Mediterranean basin about 12 Ma ago. Large areas, such as the Duero and Tajo basins, remained closed during the late Miocene, favoring the development of ponded environments and the accumulation of significant volumes of sediments which filled the basins up to present day altitudes of circa 1000 masl. These sediments represent the youngest record of internal drainage over wide areas of the Iberian Meseta, preceding the incision of the modern Duero and Tajo river valleys. Sedimentation of younger age (Turolian and Pliocene) remained restricted to small intramontane basins, such as the Teruel and Villaroya basins.

The improved age control of sedimentary sequences has helped robust interbasinal correlations, revealing common trends that can be confidently related to climate. During the early-middle Miocene transition, a synchronous shrinking of evaporitic environments followed by the expansion of fresh-water lacustrine environments is recorded in the Ebro, Tajo, and Calatayud-Daroca basins. This is interpreted as a large scale change towards more humid conditions, coeval with the global isotopic warming shift of the middle Miocene. This middle Miocene lacustrine expansion in the Ebro Basin was preceded by a sequence of lacustrine units which developed in the basin since the late Eocene at periods of about 2.4 myr, correlating with times of the eccentricity maxima. In north-central Iberia, lacustrine to palustrine carbonate units of late Miocene (Vallesian) age are topping the sedimentary fill of the eastern Duero, Almazán and Calatayud-Daroca Basins. The synchronous development of these widely distributed carbonate units also suggests climate forcing.

Cyclostratigraphic analysis on a number of records show evidence for orbital forcing in the alluvial-lacustrine sedimentation over a wide range of time scales, from periods of 20 kyr of precession to the million-year scale of very-long eccentricity, and over a wide range of basin scenarios. More elusive is the understanding of the pathways by which the climate signature is transmitted into the sedimentary sequences. Models must account for contrasting sedimentary responses depending on the interplay between upstream (sediment supply) and downstream (base level) controls. Accentuated basin asymmetry such that found in foreland systems may add further complexities in the interpretation of climatic signature in the sedimentary record. In the Ebro Basin, the variable balance between downstream and upstream forcing controls between different site locations could account for the contrasting development of sedimentary cycles.

Stable isotope ($\delta^{13}C$, $\delta^{18}O$) composition of Lake Slavonia mollusks from the Pliocene *Viviparus* beds in the region of Kravarsko (Cernikian, Central Croatia) *P*

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Long-lived Lake Slavonia existed during the Pliocene in the southern part of Pannonian Basin System (PBS). It was characterized by the explosive adaptive radiation of viviparid snails, which enabled establishment of regional biostratigraphy and excellent stratigraphic control of lake deposits along the southern margin of PBS. The present investigation deals with samples from the region of Kravarsko, located in central Croatia, approximately 30 km south from Zagreb. Situated on the southern margin of the Sava depression, this area represents the western-most extent of Lake Slavonia.

The study region is composed of Pliocene sediments deposited in predominantly lacustrine and some alluvial freshwater environments. Mandic et al. (2015) in their recent study recognized the history of Lake Slavonia as an independent phase in the geodynamic evolution of PBS. They introduced consequently a new regional stage Cernikian, defined by the complete depositional sequence of Lake Slavonia, and the *Viviparus* beds, respectively. In the area of Kravarsko two stratigraphic horizons are detected, Lower Cernikian *Viviparus kochanskyae* and Upper Cernikian *Viviparus hoernesi* zone.

The aim of the present study is a detailed paleoenvironmental reconstruction of Cernikian at Kravarsko based on stable isotope ($\delta^{13}C$, $\delta^{18}O$) composition of mollusk shells. A total of 52 specimens was chosen belonging to seven mollusk genera. Based on the position within the new regional stratigraphic scheme of the Lake Slavonia their ages are determined from c. 4.5 Ma to c. 2.0 Ma. The samples of *Viviparus kochanskyae* Zone (upper part of Lower Cernikian) were collected from outcrops which are mostly clayey to silty in composition. They mark the Early Cernikian transgression in this area. Samples from upper Cernikian *Viviparus hoernesi* Zone (strongly sculptured viviparid shells) were collected from outcrop with predominantly silty to sandy sediments. They mark the second lacustrine transgression of Lake Slavonia, which coincides with the Pliocene Climate Optimum (PCO).

In the Lower Cernikian, $\delta^{18}O$ values range from -11.2 ‰ to -1.9 ‰ (VPDB), whereas $\delta^{13}C$ values range from -11.8 ‰ to -5.4 ‰ (VPDB). In the Upper Cernikian $\delta^{18}O$ values range from -11.3 ‰ to -10.1 ‰, and $\delta^{13}C$ values from -11.7 ‰ to -7.4 ‰. Therefore, total ranges of the $\delta^{13}C$ record are fairly similar in both horizons. In contrast, $\delta^{18}O$ values show a wider range in Lower Cernikian than in the Upper Cernikian. This variability is probably related to different habitat preferences and life-strategies of evaluated gastropod taxa. It might also result from a larger number of species measured from the *Viviparus kockanskyae* Zone.

In the future, our stable isotope data will serve as the basis for paleoenvironmental and paleotemperature reconstructions of Lake Slavonia in correlation with known temperature data for period of warm Pliocene Climate and also for PCO. Also it will serve for an evaluation of the impact of mollusk life-strategies and habitat preferences on expected isotope signatures (e.g., Harzhauser et al., 2007; 2012).

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Mandic, O., Kurečić, T., Neubauer, T.A., Harzhauser, M. 2015. Stratigraphic and paleogeographic significance of lacustrine mollusks from the Pliocene Viviparus *beds in central Croatia. Geologia Croatica 68 (3): 179–207.*

Subsurface distribution model of the "Post-Cardids" Neogene of Vojvodina (Northern Serbia) *P*

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Palaeogeographic distribution and the stratigraphic-depth position of the Pliocene lacustrine-fluvial sediments have a great significance in the context of current Neogene geological considerations of the Pannonian basin. The term "Post-Cardids" Neogene indicates a significant biostratigraphic event which marks the end of well-known evolution of the endemic mollusks of Lake Pannon. The disappearance of Limnocardids and some other saline lake dwellers is the one of crucial criteria for the Miocene/Pliocene boundary (Janković, 1970). The subsurface distribution pattern a predominantly lacustrine-fluvial Post-Cardids Neogene was based on the original map of the first author (Marinović, in press). Basically, the mentioned map at a scale 1:200.000 has a regional-prognostic character and is constructed on the basis of more than 600 hundred boreholes (200 of them with the fossil content) drilled during the last 50 years. It represents the author's interpretation of the averaged depth-level of transition from more caspibrackish-lacustrine sediments ("upper Pontian") to the lacustrine-fluvial deposits (Lower *Paludina* Beds s.str.). The map is constructed primarily on the basis of paleontological facts relevant for the delimitation of the aforementioned formations, and data were correlated with geophysical logs. Variable configuration of the delimitation depths, ranging to 1600 m on the boundaries of northern Banat, was adapted by structural elements that were interpreted on the seismic sections. This great data base is further updated investigations of junior authors and facts collected from many boreholes and outcrops. For example, in the area west of Beočin (boreholes B-115, elevation at 198 m), the Lower *Paludina* Beds (Dacian) were identified in the depth interval between 5.5–27 m. Numerous mollusks and ostracods were found (*Viviparus neumayri, Melanopsis lanceolata, Dreissena polymorpha, Theodoxus semiplicatus, Bithynia vukotinovici, Neglecandona paludinica, Zonocypris membranae*, etc.). At the right-hand bank of the Danube River near the „Freedom" bridge at Sremska Kamenica (e.g. borehole BP-2, elevation on 106.5 m) the *Paludina* Beds were discovered in the depth interval between 5.6–76 m. Findings of lightly sculptured viviparids such as *Viviparus stricturatus* and other freshwater fauna indicate the Middle *Paludina* Beds (Lower Romanian). Furthermore, near the Orlovat loess plateau, depending on the position of structural wells, the Middle *Paludina* Beds with *V. bifarcinatus* and *V. stricturatus* are proven in depths between 135 and 320 m, near Plandište in SE Banat at 335 m, and near the village of Lokve at the depth of 477 m. Also, they have been identified in the central Banat in different depth intervals: near the village of Boka (455–571 m), at the Elemir structure (520–548 m), Begejci (696 m), near Kumane (765 m) and Melenci (832–844 m). In the northern Banat near Kikinda, they are found between 885–956 m. Similarly, the Upper *Paludina* Beds (predominantly with *V. pilari*) were determined in different intervals near Plandište at depth of 250–335 m or in Melenci between 600–653 m. The uppermost part of these beds contains *V. ornatus* and *V. hoernesi* such as at the Elemir structure in depth of 276 m. However, on the left-hand bank of the Danube River, near the "Žeželj" bridge in Novi Sad (elevation at 85.8 m), the strong sculptured viviparids (e.g. *V. sturi*) and numerous unionids were drilled immediately below the Quaternary alluvial sediments. Furthermore, based on spatial distribution of the Pliocene deposits and their elevation it is possible to mark the main neotectonic structures and processes that led to the present

status of these sediments. The Pliocene–Quaternary tectonic compression reactivated some older structures whereby the Pliocene sediments were differentially displaced and lost its lateral continuity. As a result, the *Paludina* Beds are exposed at different altitudes on the northern and southern flanks of the Fruška Gora horst structure (Rundić et al., in press).

Janković, P. 1970. Paludina *Beds in Vojvodina. Proceedings of the VII Congress of Geologists of Yugoslavia 1: 103–115. (In Serbian)*

Marinović, D. (in press). The Map of the base of the Post-Cardium Neogene of Vojvodina (Serbia). Reports of the Serbian Geological Society for the year 2015.

Rundić, Lj., Vasić, N., Životić, D., Bechtel, A., Knežević, S., Cvetkov, V. (in press). The Pliocene Paludina Lake of Pannonian Basin: New evidence from Northern Serbia. Annales Societatis Geologorum Poloniae 86.

Sarmatian evaporites in the Zagyva Trough (North Hungary) *P*

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The area around Szirák in North Hungary was part of the Paratethys Sea in the Sarmatian (Middle Miocene). This part of the Central Paratethys belonged to the Zagyva Trough, which had been formed as a result of a NW–SE extension.

The thickness of the Sarmatian succession in borehole Szirák-2 exceeds 500 m (763.5–1270 m) (Hámor, 1992). The marine Badenian sequence is overlain by evaporitic Early Sarmatian deposits, followed by marl, then with a continuous transition into the Pannonian sediments.

We resampled the cores in 2015 and reexamined the material. In the present study we focus on the microfauna of the Lower Sarmatian evaporitic succession and that of its boundary beds.

The evaporite-bearing beds (Budajenő Formation) in the lower part of the Sarmatian succession (1150.5–1270 m) were formerly thought to have been deposited in shallow-water, semi-restricted lagoon environment. As a result of our revision it turned out that the lower (1210.5–1258.7 m) section of the Budajenő Formation was deposited in deeper (mid to deep sublittoral) environment (water depth of 30–120 m is estimated). This idea is based on the foraminiferal assemblage dominated by the newly found *Anomalinoides dividens*, which occurs together with e.g. *Buliminella elegantissima* (d'Orb.), *Bolivina sarmatica* Didk., *Ammonia beccarii* (L.), *Lobatula lobatula* (W. & J.) and is accompanied by the ostracods *Cythereis sarmatica* (Jir.) and *Xestoleberis fusca* Schn. In borehole Tengelic-2, drilled in probably similar palaeogeographic setting 170 km to the SW of Szirák, sedimentation took place in a maximum 50 m-deep environment (Bohn-Havas, 1982; Korecz-Laky, 1982). Similarly to that, the small size of the microfauna – presumably due to the high salinity content – was also remarkable in the Szirák-2 succession.

This contradiction can be eliminated by the conception of a local anti-estuarine circulation between the Zagyva Trough basin and the Sarmatian open waters, due to the formation of a sill triggered by tectonic movements. Thus, the deep water outflow from the Zagyva Trough was restricted, and it led to the formation of evaporites (anhydrite) from the brine at the bottoms.

The *Anomalinoides dividens* dominated association shifted into a Miliolidae dominated assemblage in the upper part of the Budajenő Formation. This indicates the shallowing of the

water depth (< 30 m) and the persistence of the high salinity conditions.

In the closing marine marl layer (Kozárd Formation) of Late Sarmatian age (763.5–1150.5 m) a rather poor foraminiferal assemblage comprising *Ammonia, Elphidium* and *Nonion* has been revealed, whereas in the basal beds of the Pannonian succession the *Trochammina-Miliammina* association was identified, which indicates very shallow, lagoonal/ swamp environment with rich vegetation (Fuchs & Schreiber, 1988; Korecz-Laky, 1985).

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Fuchs, R., Schreiber, O. 1988. Agglutinated foraminiferal assemblages as indicators of environmental changes in the early Pannonian (late Miocene) of the Vienna Basin. Abh. Geol. Bundesanst. 41: 61–71.

Hámor, T. 1992. A Szirák–2. sz. alapfúrás földtani eredményei. Annual Report of the Geological Institute of Hungary 1990: 139–168.

Korecz-Laky, I. 1982. A Tengelic 2. sz. fúrás miocén Foraminifera faunája. Miocene Foraminifera fauna from the borehole Tengelic–2. Annals of the Hungarian Geological Institute 65: 151–187. (in Hungarian, with English abstract)

Korecz-Laky, I. 1985. Foraminiferen im Pannon Ungarns. In: Papp, A., Jámbor, Á., Steininger, F.F., (eds.) Chronostratigraphie und Neostratotypen, Miozän der Zentralen Paratethys, v. VII, M6 Pannonien (Slavonien und Serbien): 265–269; Budapest (Akad. Kiadó).

Pliocene lake deposits and the Pliocene/Quaternary boundary at the Fruška Gora (Serbia): an integrated study

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A new research from the Fruška gora Mt. in northern Serbia sheds new light on the physicochemical conditions, ecology and evolution of the "*Paludina*" Lake (i.e. Lake Slavonia after Harzhauser & Mandic, 2008; Mandic et al., 2015). An integrated study combines sedimentology, sequence stratigraphy, biostratigraphy, palaeontology, palaeobotany, coal petrology, organic geochemistry and magnetic mineralogy. The sedimentary succession studied in the Sremski Karlovci clay pit (Rundić et al., in press) represents the lake margin at the foot of the eastern part of Fruška Gora ridge. Sedimentary facies reveal minor and major lake-level changes, including a forced regression with fluvial valley incision in the succession middle part and the ultimate emergence and covering of the lake floor by Pleistocene loess. Mollusc and ostracod fauna indicates an oligohaline shallow calm-water environment, no deeper than 5–6 m, with an active inflow of spring water (Krstić, 2006). The lake local depth during transgression maxima did not exceed 20 m. Organic geochemical analyses indicate a rich and diversified assemblage of gymnosperm plants with a contribution of angiosperms, weeds and microbial biomass in the peat-forming suboxic to oxic coastal swamp environment. Maceral analysis of organic matter shows a prevalence of mixture detro- and telohuminite, accompanied richly by inertinite in lignite and by liptinite in clay. The Pleistocene shift to terrestrial semiarid environment resulted in oxidizing groundwater conditions, with the reddening of sediments around a fluctuating groundwater table and the diagenetic trans-

formation of bacteria-derived greigite into magnetite (Rundić et al., in press). In regional stratigraphy, the occurrence of *Viviparus neumayri* in the lower part of the succession (e.g. Sremski Karlovci clay pit, Čerević clay pits, a few boreholes west of Beočin, small outcrops along the right bank of Danube River, etc.) indicates the Lower *Paludina* Beds of Dacian Stage (early Zanclean age). Other lightly sculptured viviparids such as *Viviparus stricturatus* and certain ostracodes indicate to the Middle *Paludina* Beds (e.g. Sremski Karlovci clay pit, Sremska Kamenica area, etc.) of lower Romanian Stage (late Zanclean–early Piacenzian). In the Sremski Karlovci clay pit, the upper part of the section lacks age-diagnostic fossils and is considered to represent Middle *Paludina* Beds possibly with an erosional relic of Upper *Paludina* Beds at the top – below the Pleistocene loess cover. On the other hand, at the left bank of the Danube River, near the „Žeželj" bridge in Novi Sad, the *Paludina* Beds are drilled directly below the Quaternary alluvial sediments. The strong sculptured viviparids such as *Viviparus sturi* indicate to the Pliocene climate optimum (Mandic et al., 2015) which corresponds to the Upper *Paludina* Beds of Upper Romanian Stage (Piacenzian-Gelasian). For the reasons of inadequate correlations of regional stages within the Paratethys, it is proposed that a sedimentation cycle that involves all the Paludina beds integrates under the name of new regional stage – Chernikian, which covers a time span of 4.5–2.0 Ma (Mandic et., 2015). Actually, its youngest part that corresponds to the Upper Paludina beds would represent the oldest Pleistocene (Gelasian). If all this is true, then a younger part of Pliocene stratigraphic succession represented by alluvial deposits below the well-known the loess-paleosoil sequences (e.g. Sremski Karlovci clay pit) could be the base of the Quaternary in this area.

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Mandic, O., Kurečić, T., Neubauer, T.A., Harzhauser, M. 2015. Stratigraphic and palaeogeographic significance of lacustrine molluscs from the Pliocene Viviparus *beds in central Croatia. Geologia Croatica 68 (3): 179–207.*

Rundić, Lj., Vasić, N., Životić, D., Bechtel, A., Knežević, S., Cvetkov, V. (in press). The Pliocene Paludina Lake of Pannonian Basin: New evidence from Northern Serbia. Annales Societatis Geologorum Poloniae 86.

Late Burdigalian sea retreat from the North Alpine Foreland Basin: new magnetostratigraphic age constraints [P]

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Accurate paleogeographic reconstruction of the North Alpine Foreland Basin (NAFB) during the Burdigalian (Early-Middle Miocene) is hampered by a lack of reliable age constraints. In this high resolution magnetostratigraphic study we try to solve a long-lasting age bias for the onset of freshwater deposition in the neighboring S-German and Swiss Molasse basins. We

measured ~600 samples from eleven drill cores covering the transition from marine to brackish to freshwater environments in the S-German Molasse Basin. The composite magnetostratigraphic pattern of these cores provides two possible age correlation options (model 1 and 2). In model 1, the base of the brackish succession lays within C5Cr (~16.7–17.2 Ma), and the onset of freshwater deposition has an age of ~16.5 Ma. Correlation model 2 suggests the transition to brackish conditions to be within C5Dr.1r (~17.7–17.6 Ma), and yields an age around 16.7 Ma for the shift to freshwater environments. Most importantly, both models argue for a latest Burdigalian age of 16.6 ± 0.1 Ma for the retreat of marine conditions in the central NAFB, which is approximately 0.7 myr younger than previously suggested. We discuss the implications of our new age for the biostratigraphically important 'Kirchberg Fm' (*Rzehakia Beds*) and present revised paleogeographic reconstructions of the NAFB in the late Burdigalian.

A middle Miocene age for the Popovac Lake (Serbia): Ar/Ar dating and magnetostratigraphy in the Serbian Lake System

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The Miocene Serbian Lake System (SLS) represents a series of endemic lakes that were located southeast of the Pannonian Basin in the junction area between the Dinarides and South Carpathians. So far, no independent age constraints are known from the Serbian lakes, and estimates for the age of the lacustrine infill range from 17–14 Ma (e.g. Krstic et al., 2012). New age constraints for the SLS could improve this and allow comparison to similar environments such as the Dinaride Lake System. In this study we used magnetostratigraphy and radioisotopic dating to quantify the age of the ~70 m thick, fine-grained lacustrine series in the Popovac basin (Serbia). One sanidine-bearing tuff provided a very reliable total fusion $^{39}Ar/^{40}Ar$ age of 14.40 ± 0.01 Ma including all errors using the approach of Kuiper et al. (2008). The paleomagnetic results show a normal polarity pattern with a 2 m-thick reversed interval in its lower part. If we take the Ar/Ar into account, the normal polarity can be correlated to Chron C5ADn in the Global Polarity Time Scale (Hilgen et al., 2012). The reversed interval is too short to fit and suggests that part of the magnetic carrier is of secondary origin. At least 12 climate-induced obliquity or precession cycles are interpreted based on alternating dark marl/silt with light-colored limestone patterns and geophysical proxies.

Our new age suggests that the deepest lake phase in Popovac existed around 14.4 Ma (late Langhian), which coincides with a peak of subsidence in the south-eastern Pannonian Basin between 15–14 Ma (e.g. Stojadinovic et al., submitted). This is after the Miocene Climatic Optimum, and ~1 Myr later than deposition in most Dinaride Lakes (De Leeuw, 2011). Moreover, the new age suggests that the 'Badenian' marine transgression flooded the area only after 14.4 Ma.

De Leeuw, A. 2011. Paleomagnetic and geochronologic constraints on the Miocene evolution of semi-isolated basins in southeastern Europe. PhD Study, Utrecht University.

Kuiper, K.F., Deino, A., Hilgen, F.J., Krijgsman, W., Renne, P.R., Wijbrans, J.R. 2008. Synchronizing rock clocks of Earth history. Science 320: 500–504.

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Stojadinovic, U., Matenco, L., Andriessen, P., Toljić, M., Rundić, Lj., Ducea, M.N. (submitted). Structure and provenance of Late Cretaceous – Miocene sediments located near the NE Dinarides margin: inferences from mechanics of orogenic building and subsequent extensional collapse. Tectonophysics.

Linking bio- and chronostratigraphy in Lake Pannon: pyroclastics and biozones in the southwestern Pannonian Basin

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In the lack of marine fossils, the dating of lacustrine successions is often problematic. Even where a local biostratigraphy can be based on endemic faunas, it should be tied to "absolute" chronology in order to be correlatable beyond the given basin. This is especially the case with the late Neogene sediments of the Pannonian Basin. The more than 4 km thick deposits, accumulated in Lake Pannon during a long time span of approximately 7 million years, are subdivided mainly using mollusc and dinoflagellate biozones. However, there are very few tie-points available to calibrate these zones against chronostratigraphy.

Here we present a site from the SW Pannonian Basin, Pécs-Danitzpuszta in the Mecsek Mts., Hungary, where a direct linkage between bio- and chronostratigraphy can be attained. This large outcrop of lower Upper Miocene sediments of Lake Pannon is composed of offshore white marls overlain by a sandy succession and has a good mollusc and ostracod record in both units. A few centimeters thick, biotite-rich tuff layer was found in the uppermost part of the white marls. The composition and sedimentary features indicate primary origin by ash fall, presumably in a distal position from the source.

Biostratigraphically the succession containing the tuff interbed belongs to the *Lymnocardium schedelianum* sublittoral mollusc biozone, which corresponds to the age range of ca. 11 to 10.2 Ma. K/Ar dating of the tuff layer carried out on altered biotite and fresh volcanic glass gave an isochron age of 11.8 ± 0.2 Ma. Detailed petrological study of the tuff showed a peculiar mineralogical assemblage (plagioclase, K-feldspar, biotite, amphibole, augite, aegirine-augite, aegirine and apatite) in addition to fresh glass shards. This suggests eruption of alkaline magmas, presumably that of the alkaline trachyte volcano at Pásztori located in over 200 km distance, in the northwestern Pannonian Basin. This offers further correlation possibilities. The Pásztori volcano was dated to 13.3 to 8.6 Ma with the K/Ar method, whereas the zircon fission track dating yielded 11.4 ± 0.6 Ma and 12.3 ± 0.8 Ma ages. In order to obtain more precise ages, we conducted laser ablation zir-

con U-Pb geochronology on rare zircon grains from an alkaline trachyte sample and got an age of 10.4 ± 0.3 Ma.

These data have a wide range and some of them represent disagreement between bio- and chronostratigraphy. Work is ongoing to resolve this discordance. However, the case offers a unique possibility to directly correlate various methods against each other, possibly to correct the temporal boundaries of mollusc biozones previously estimated by indirect methods, and to take a step towards a solid stratigraphic framework for the lacustrine sequence of the Pannonian Basin. The occurrence of the tuff in the southern part of the basin shows that volcanic ashes were transported by the wind and preserved at relatively large distances in the Upper Miocene lacustrine sequence. Thus, it could be an important marker horizon throughout this area. Although probably not numerous, volcanic marker horizons like the presented one might be widespread in the Pannonian Basin and should be looked for, because they greatly enhance the dating possibilities of the otherwise problematic lacustrine succession.

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SESSION D. GEODYNAMICS

KEYNOTE

Lake basin evolution dynamics – tectonic control of depositional processes in isolated settings

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The large number and distribution of syn- to post-orogenic extensional systems in Mediterranean orogens infers the possibility of the formation and evolution of isolated lacustrine sedimentary basins, driven by different tectonic mechanisms. Classical models of orogenic evolution assume that back arc basins form in the hinterland of orogens, collapsing the upper plate above oceanic subduction zones. This is a common characteristic thought to apply to all low-topography orogens of Mediterranean type driven by the fast roll-back of genetically related slabs. In the case of the Dinarides, such an extensional evolution is recorded both far at the interior of the orogen creating the larger Pannonian Basin, but also superposed over the main mountain chains, demonstrating the gradual migration of the couple contraction - extension towards the Adriatic foreland. Such a migration may result in a complex evolution of the Miocene sedimentary basins that change from contractional to extensional as a function of the spatial position of the back-arc mechanics at any given time. Mediterranean orogens often diverge from the typical scenario by widespread extensional deformation taking place during moments of continent-continent collision and by the interference of such deformation driven by different subduction zones. For instance, the formation of the Pannonian back-arc basin is generally related to the rapid Miocene roll-back of a slab attached to the European continent. The present-day extensional geometry of the Pannonian back-arc formed essentially during the Carpathians collision and was also driven by an additional Middle Miocene roll-back of a Dinaridic slab. As a result, crustal thickening takes place in the foreland of the orogen, while the gradual extension is migrating and thinning the crust in a foreland direction. The mechanics of extension is of key importance for the stability of the Dinaridic lakes. As long as the extension remained asymmetric at the beginning of its evolution, the subsidence in the normal faults hanging-wall remained moderate and the basins evolved in continental alluvial to lacustrine environment. When the extension changed to symmetric, the larger amounts of regionally induced subsidence connected the lakes and ultimately resulted in their partial connection with the marine realm. These observations demonstrate the need for an active reconsideration of coupling the endemic biostratigraphy with existing orogenic models of contraction and extensional evolution, which should include an active investigation of the role of continental subduction during various phases of mountain build-up and back-arc collapse.

The link between tectonics and sedimentation in asymmetric extensional basins: inferences from the study of the Sarajevo-Zenica Basin

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In tectonically active basins, depositional geometry is dominantly controlled by the balance between basin subsidence enhanced by the pulses of fault activity and coeval footwall uplift and erosion influencing sediment supply. In extensional basins, coupled tectonic and depositional history is usually described in terms of stratigraphic sequences linked with the activity of normal faulting. The interplay between deposition and normal faulting stages is less understood in basins bounded by major extensional detachments or normal fault systems associated with significant exhumation of footwalls. The link between sedimentation and tectonic during the spatial and temporal migration of deformation across the basin is especially interesting. The optimal place to study coupled depositional-kinematic history is the Sarajevo-Zenica Basin, located in Bosnia and Hercegovina. This is the largest intramontane basin in the Dinarides. The basin fill overlays pre-existing orogenic fabrics and records Late Oligocene–Miocene lake evolution deposited in an endemic and isolated environment. An integrated study of field kinematics and detailed sedimentological mapping in outcrops correlated with earlier local and regional studies enables us to derive a high-resolution evolutionary model of the basin. The new results suggest a close relation between moments of normal faulting and associated high-order sedimentological cycles. The overall extensional basin was filled by sediments deposited by flows dominantly draining the neighbouring uplifting mountain chain. The temporal and spatial migration of synthetic listric normal faults across the basin created an overall regressive, coarsening upwards depositional cycle with a strong asymmetric depositional geometry. This lower order cycle comprises three higher order transgressive-regressive cycles driven by the individual moments of normal faulting. This Early - Middle Miocene extensional deformation is the most external area in the Dinarides, documented so far, to be affected by extension of the neighbouring Pannonian Basin.

The deformation was predated and postdated by two phases of contraction. The Oligocene - Early Miocene phase of contraction took place during the final stages of the Dinaric collision and was related to the onset of deposition in the basin. The post-Middle Miocene phase of contraction inverted the basin fill by reactivating the earlier basal listric detachment. This event is correlated with the regional indentation of the Adriatic continental unit.

Geodynamic controls of organic matter deposition in lacustrine basins: The case of Miocene pull-apart basins in the Eastern Alps

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The evolution of the Eastern Alps was controlled by large-scale extension and lateral tec-

tonic extrusion in Early to Middle Miocene times. Main eastward movements of the central parts of the Eastern Alps occurred along sinistral NE- and dextral SE-trending strike-slip faults. Consequently, pull-apart basins were formed along the sinistral Mur-Mürz fault system (Noric Depression) at major oversteps. The more than 2 km deep Fohnsdorf Basin, the 1 km deep Trofaiach Basin and the relatively shallow Leoben, Aflenz and Parschlug basins were formed in the central part of the Mur-Mürz fault system. The SSE-trending Pöls-Lavanttal fault system comprises 12 km of accumulated dextral strike-slip movement and vertical offsets of several kilometers since Miocene times. Several basins, including the asymmetric Lavanttal Basin with a > 2 km thick Miocene succession, are aligned along this fault system.

Basin evolution along the Noric Depression started in the Late Karpatian/Early Badenian. Sedimentary sequences are usually similar, comprising coarse-grained alluvial, fluvial and fluvio-deltaic sediments at the base, often followed by coal seams overlain by sapropelic rocks and fine-grained sediments which were deposited in a lacustrine (partly brackish) environment with high subsidence rates. The top of the succession is frequently characterized by a coarsening-upward sequence terminated by coarse-grained fluvial gravels, deposited after the present lakes filled up in times of tectonic quiescence.

The Fohnsdorf and Leoben basins contain more than 10 m of sub-bituminous coal. Although they accumulated in similar ages, similar tectonic settings, and similar stratigraphic position within the sedimentary sequence, variable conditions during peat accumulation resulted in differing coal properties. properties of the coals and therefore peat accumulation differ significantly. Whereas the ash- and sulfur-rich Fohnsdorf coal was deposited in a low-lying mire, the main body of the Leoben coal formed in an ombrotrophic raised mire.

Basin evolution in the Lavanttal Basin, also commencing with coarse-grained fluvial sediments in the ENE-WSW striking Granitztal, started slightly earlier (Ottnangian/Karpatian). In comparison to the Noric Depression, no coal seams exist in the transition between fluvial and lacustrine environments in the Badenian. Furthermore, after deposition of the lacustrine to brackish lower part of the Badenian Mühldorf Formation, marine conditions established in the upper part of the Formation (Middle Badenian). Salinity decreased and freshwater conditions prevailed during Late Badenian.

Whereas deposition stopped in the Late Badenian along the Noric Depression, deposition continued after a sea level fall and consequent erosion at the Badenian/Sarmatian boundary. The subsequent transgression is visible in brackish sediments at the base of the Sarmatian succession. The Sarmatian is characterized by brackish and freshwater sediments which host several, partly economic coal seams. Frequent sea level fluctuations and a constant slow subsidence lead to the formation of these seams.

Gas-prone coals and oil-prone sapropelic shales, frequently overlying coal seams, accumulated during initial stages of lacustrine deposition. Sapropelic shales indicate drowning mires, caused by elevated subsidence rates. In the Noric Depression, these shales show hydrogen indices (HI) up to 300 mgHC/gTOC, pointing to a certain oil potential. Brackish conditions in the Fohnsdorf Basin suggest a connection to the Miocene sea which existed in the Lavanttal Basin. Sapropelic shales above Sarmatian coal seams in the Lavanttal Basin reach HI values up to 480 mgHC/gTOC, again suggesting a source potential for oil.

In comparison to the Noric Depression, lacustrine to brackisch sediments of the Mühldorf Formation, deposited in the Early Badenian in the Lavanttal Basin, show high total organic carbon (TOC) contents (up to 10 %) and high HI values (up to 600 mgHC/gTOC), suggesting a kerogen type II resulting from algal blooms. A transgression led to marine conditions in the upper part of the Mühldorf Formation, where

TOC contents around 1–2 % and HI values below 200 mgHC/gTOC occur due to low production rates.

Upper Miocene sedimentation processes in Croatian part of Pannonian basin based on results of 3D seismic interpretation *P*

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The study presents geological data related to sedimentation process which resulted in filling of Croatian part of Pannonian basin (Upper Miocene). Conclusions are based on 3D seismic interpretations for development and exploration purposes in oil industry. Approach used in the interpretation was multidisciplinary and included seismic interpretation and analyses, stratigraphy and petrophysics as well as sedimentological core analyses.

Main target is exploration and development of sandstone reservoirs, in deeper parts of Drava depression, related to existing HC fields and their correlation on broader area between them. The process covered therefore regional to single well approach. Regional approach included seismostratigraphical interpretation on 3D seismic dataset and corresponding well log correlation as well as sedimentological core analyses. The result was regional sedimentological frame which was filled with detailed interpretation of sandstone reservoirs on multiple levels, field scale. Detailed seismic attribute analyses enabled delineation of sedimentological bodies. Together with well log interpretation and sedimentological core analyses it revealed the sedimentation mechanism as a part of broader sedimentation process (frame) which filled the Drava depression.

Since the Upper Miocene (Pannonian and Pontian) represents the majority of sediments in the area of interest its mechanism of sedimentation indicate overall process of Drava depression filling. The result of this work is sedimentological model which is applicable to or at least good starting point for other parts of Pannonian basin. Indeed, very similar experience is also present in Sava depression.

Lake Pannon sedimentation model in the Legrad field area (NW Croatia)

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The Neogene to Quaternary Lake Pannon sedimentary successions of the SW part of the Pannonian Basin are characterized by three 2nd order megacycles divided by major regional unconformities. In here described sediments are related to the transtensional post-rift thermal basin subsidence and belong to the second megacycle between the Base Pannonian to the Base Pliocene unconformity

For the interpretation of the genesis and evolution of the wider depositional area around the recent gas field Legrad in the NW Croatia interdisciplinary approach were used.

Information on lithology, ichnology, sedimentary structures and structural elements were obtained from complete macroscopic examination of cores. Petrophysical and calcimetry measurements, detailed petrographical (and microporosity) and palynological analyses were done. Geochemical evaluations were considered. All available well data were correlated and calibrated with well log and seismic data. Paleorelief features (like channel position and their direction) are visible on coherency time-slices.

Investigated deposits and related cores are presented by alteration of sandstone, siltstone and marls. Sandstones, generally lithic arenites, are very well cemented with intergranular porosity. They are moderately sorted, with grains in the range from very fine to medium sand size. Sandstones are sporadically rich in organic matter. Siltstone is also well cemented. Marls occasionally contain smaller amount of siliciclastic component and pyrite occurrences. Open and reduced microfractures are sometimes visible.

Sandstones are largely homogenous and thick to several meters. Horizontal and cross-lamination are detected only in uppermost part of the studied sedimentary succession (Lower Pontian deposits). Soft sediment deformation structures like load casts, ball-and-pillow and flame structures are relatively frequent. Rip-up marl clasts are sporadically observed suggesting channel sedimentation. Subvertical bioturbation is common. Terrigenous organic matter (phytoclast debris) are ubiquitous.

Palynological macerals of the cored sediments in the lower part of the investigated interval are rich in organic contents. Most of the palynofacies (70–80 %) is amorphous matter. Liptinite kerogene, generally made of weakly diverse dinocyst assemblage, some pollen grains (mostly bisaccate) and a few green algae remnants (*Botryococcus brauni*), completed the organic residue (10–20 %). Lignohumine clasts are scarce. Macerates are biodegraded. Pyrite inclusions in palynomorphs are frequent. Index fossils *Spiniferites bentorii* and *S. bentorii oblongus* specify the Upper Pannonian age. By the biostratigraphical classification of the organic walled microphytoplankton, samples belong to *Spiniferites bentorii* main zone, to the *Spiniferites bentorii oblongus* subzone. Younger sediments, although somewhat different, are also rich in organic matter. Lignohumine clasts of variable sorts and size make 30–60 %, while amorphous matter makes 30–40 % of total organic matter content. Liptinite component, composed of dinocysts, some freshwater alga (*Pediastrum simplex*, *Spirogyra* sp.), various polled grains (chiefly bisaccate) and a few spores, make 10–20 % of palynofacies.

The Lower Pontian age is confirmed by *Spiniferites balcanica, S. bentorii coniunctus* and *S. validus*. According to the dinocyst palynozonation, samples belong to *Spiniferites balcanica* main zone, to the *Spiniferites bentorii coniunctus* subzone.

Sediments originate in lacustrine environment as channel (and interchannel) deposits and subaquatic fans caused by gravity flow mechanisms (mostly turbidites). The Late Pannonian sedimentation took place in slightly deeper environment of decreased salinity, moderately distant to shore and terrigenous influx. The Early Pontian sediments were created in also somewhat distal and deeper freshwater environment but in the zone of the significant terrigenous influence.

Tectonically oriented paleomagnetic study of the Pag and Drniš-Sinj intramontane basins, External Dinarides

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Magnetostratigraphy studies for a number of Miocene intramontane basins of the Dinarides documented that the lake sediments were good targets for paleomagnetism. Subsequent to the publication of magnetostratigraphy results from a series of sections (Mandic et al., 2008; Jiménez-Moreno et al., 2009; De Leeuw et al., 2010), we collected samples in 2011 from two of the

basins, Pag and Drniš-Sinj for tectonic interpretation. In these basins lacustrine sedimentation took place, characterized by low sedimentation rate of predominantly carbonate material with tephra (Sinj basin) coal and bentonite intercalations (Pag Island). Post-depositional deformation affected the basin sediments in a non-uniform manner and intensity. In Pag Island, the Miocene basin sediments crop out in the 1200m long Crnika section. As several segments of it were obviously detached, we sampled the oldest and youngest segments, which seemed to be in situ, the former from the reversed, the latter from the normal polarity zone. The paleomagnetic directions obtained for the two parts were statistically different before tilt corrections, and remained so after restoring the strata to horizontal. A repeated visit to the section revealed that modern gravity–driven creeping can account for this, i.e. the results from the Pag basin should be rejected from regional tectonic interpretation.

From the Drniš-Sinj basin eight geographically distributed Miocene localities and one Santonian yielded good paleomagnetic mean directions. Positive tilt test proved the pre-tilting age of the remanence for seven sedimentary localities. The overall-mean paleomagnetic direction implies CCW rotation of 13–20° with respect to Africa and 21–27° with respect to stable Europe, during the last 15 million years. A tephra intercalation with secondary remanence suggests similar rotation. The angle of the CCW rotation for the Santonian locality is somewhat larger than the one for the Miocene.

The above conclusions are different from those by De Leeuw et al. (2012) for the Pag and Sinj basins, although the published paleomagnetic directions for the respective parts of the Crnika and the Lučane sections (in the latter case using simple tilt correction) are very similar. However, we had to come to the conclusion that the Crnika section must be excluded from regional tectonic interpretation, as it was discussed above. Concerning the Drniš-Sinj basin Lučane section belongs to a plunging structure and full tectonic correction has an effect on the declination. Even more important is that a paleomagnetic direction based on geographically distributed localities with different local tectonic positions, enhances the tectonic significance of a paleomagnetic result.

As the External Dinarides are the loci of a complicated network of Miocene and even younger tectonic zones, we cannot export the observed rotation for the whole unit, but consider our results as one more step for the kinematic constraints of the post-Oligocene tectonic history of the External Dinarides.

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Plio-Quaternary intramountain basins of southeastern Slovenia: first steps towards landscape evolution model *P*

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This study targets Plio-Quaternary intramontane basins of the southeastern part of Slovenia that structurally lies at the junction of three large entities: Southern Alps, Dinarides and Pannonian basin. In Cenozoic the landscape evolution of this area was strongly influenced by Alpine-Dinaric tectonic processes. Tectonic activity caused not only formation of an undulating landscape with intramontane basins, but also strongly influenced the concurrent terrestrial sedimentation. From late Neogene onward, the terrestrial sediments, traditionally called "Plio-Quaternary" gradually infilled intramontane basins. Due to the spatial and temporal diversity of the sedimentation, the sediments have not been unambiguously characterized so far. State of the art knowledge interpreted these deposits as shelf-edge deltas molasses deposits, or as terrestrial sediments deposited in intramontane basins. The sediments are preserved in topographic depressions, as well as in highs, indicating that tectonics also played an important role after their deposition. The main aim of this study is to develop a landscape evolution model of the southeastern Slovenia from the Pliocene onward. For this aim a detailed investigation of composition, provenance, genesis, age and uplifting/subsiding rates of these sediments is needed. First results suggest that the "Plio-Quaternary unit" has diverse composition and genesis, ranging from fluvial deposition to thick residuals of bedrock weathering. Subunits vary from pure clays to sands and gravels. The residual of bedrock weathering subunit will also be investigated in detail since composition of the residual partly indicates its transport rather than in situ weathering only.

Correlation of Late Miocene lacustrine to fluvial lithostratigraphic units in the Danube–Kisalföld Basin (Slovakia, Hungary) *P*

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The northwestern subbasin of the Pannonian Basin System is crossed in the middle by the Danube river which marks the international boundary between Slovakia to the north and Hungary to the south. The basin is called "Danube basin" in Slovakia and "Kisalföld" in Hungary. The lithostratigraphic subdivision of the more than 4 km thick Upper Miocene to Pliocene sedimentary succession of the basin, deposited in Lake Pannon and in the adjacent fluvial environments, has been developed independently in the two countries. A careful study of the sedimentary formations across the entire basin, however, led us to claim that these formations are identical or similar between the two basin parts to such an extent that their correlation is indeed a matter of nomenclature only. Nemčiňany Formation corresponds to Kálla Fm., representing locally derived coarse-grained deltas and gravelly shores along the basin margin developed during the early transgressive phase of Lake Pannon (11–9.5 Ma). The

deep or open lacustrine sediments are collectively designated Ivanka Formation without considering genetics in Slovakia, whereas they are subdivided into four formations in Hungary depending on their position and depositional processes. Endrőd Marl is found in deep lacustrine settings and on wings of depressions (11.6–10 Ma), while Szák Claymarl marks floodings of the basement highs (ca. 10.2 and 8.9 Ma) and comprises a few meters of transgressive lag overlain by open-lacustrine fossiliferous marls. Szolnok Sandstone represents deep basin turbidite systems (10.5–9.5 Ma), and Algyő Fm comprises the fine-grained slope deposits prograding through the basin between 10–9 Ma ago. Beladice Formation represents shallow lacustrine (littoral) and deltaic deposits, fully corresponding in its definition to Újfalu Formation (10.5–8.5 Ma). The fluvial deposits, assigned into Volkovce Formation in Slovakia are designated Zagyva Formation in Hungary (10–6 Ma). The synoptic description and characterization of the formations offer a basin-wide insight into the development of this sedimentary basin during the Late Miocene. The turbidite systems, the slope, the overlying deltaic and fluvial systems are all genetically related and are coeval at any time slice after the regression of Lake Pannon initiated about 10 Ma ago. All these formations are younging to the S, SE as the progradation of the shelf-slope went on. The basin got filled up to lake level by 8.5 Ma, since then fluvial deposition dominated in areas of subsidence, transmitting huge amount of sediment further to the SW and SE parts of the Pannonian Basin.

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Structural analyses and petroleum potential along regional transects across the Dinarides mountain chains *P*

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The Dinarides can be characterized as a complex fold-and-thrust belt. Such mobile belts are likely to potentially host considerable petroleum reserves, and therefore constitute an attractive target for exploration. The first step to derive the petroleum potential of the studied area will be the focus of this project, which is the structural analysis of transects extending from the offshore in the west to the onshore in the east of the Dinaridic region. The structural analysis has been done by doing field research, using geological maps, and obtaining knowledge from already existing data and bibliography.

The Dinarides include a sedimentary basin covering northwestern Slovenia, Croatia, Montenegro, Bosnia-Herzegovina, and Albania. Paleozoic, Mesozoic and Cenozoic heterogeneous sediments (with cumulative thickness reaching up to 15 km) characterize the basin fill. Based on the age and distribution of syn-kinematic contractional turbidites (i.e. flysch), classical studies of the Dinarides have postulated an Eocene episode of major shortening in the entire Dinaridic chain. By contrast, recent kinematic and thermochronological studies infer a more complex evolution, characterized by accelerated moments of differential shortening-related exhumation that took place during Eocene–Quaternary times in the external Dinaridic nappes of Montenegro, SE Croatia and Bosnia-Herzegovina. The shortening is laterally variable along the strike of the orogen towards

the NW, where the amplitude of post-Eocene deformation is rather reduced, being apparently transferred by an unknown mechanism to more internal Dinaridic areas. Significant amounts of thrusting were accommodated in particular by the Budva-Cukali zone in the external nappes (~100–130 km) and at the lower nappe contact of the Durmitor unit in Montenegro. More to the hinterland, the contraction is partly coeval with a gradual migration of back-arc extension that generally reactivated the previous NE-dipping thrust contacts and induced large-scale exhumation of the SW-ward located footwalls along a series of detachments with variable offsets. Preliminary studies demonstrate that the extension migrated towards the external Dinarides, either creating Miocene basins (such as the Sarajevo basin) or exhuming rocks previously buried in various metamorphic degrees at nappe contacts and created large extensional klippens (such as the Durmitor nappe structure of Montenegro). Existing kinematic and exhumation data infer that the extension was subsequently followed by widespread contraction in the entire orogen starting likely around 8 Ma, generally interpreted as an effect of slab detachment in the external Dinarides and/or the indentation of the Adriatic microplate.

The second step of this project will be to balance and restore the structural sections into their initial, pre-orogenic configuration. Eventually the aim will be to subsequently perform kinematical and thermal modeling to constrain the main episodes of structural deformation, source rock maturation and hydrocarbon migration, and better predict the current petroleum potential of the studied area. Direct extrapolation from the sedimentary thicknesses preserved in synclines, paleo-thermometers such as Tmax and Ro, and 1D basin modeling on selected wells could provide crude estimates on the thickness of eroded series.

Organic geochemical and maceral composition of coal and shales from the Ibar lacustrine basin (south Serbia) *P*

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The Lower Miocene Ibar Basin is located in the innermost part of Dinarides, 200 km south of Belgrade (Serbia), covering an area of approximately 320 km^2. It is a northwest-southeast elongated tectonic depression with a maximum length of 20 km and width of 12 km which consists of several coal deposits (Ušće, Tadenje, Jarando, Progorelia) and boron mine (Pobrdje) and boron deposit (Piskanja). At present high volatile bituminous coal is exploited in two underground mines: Jarando and Tadenje, and one open pit Progorelica. The present study is based on thirteen channel coal samples, thirteen core shale samples and tree boron mineralisation samples with oil, taken at different locations of the Ibar basin. Coal samples were taken from Jarando and Tadenje underground mine and Progorelica open pit. Shale core samples were taken from Piskanja deposit, while boron samples with oil were taken from Pobrdje boron mine.

The paleorelief of the Ibar basin is made of Paleozoic, Mesozoic and Tertiary rocks. Paleozoic is represented by amphibole schist, sericite-chlorite schist, calc schist, marble and metabasic rocks. Mesozoic sedimentary rocks include Triassic limestone, dolomite, marble, sandy marlstone and marlstone, and Jurassic serpentinite, gabbro, rodingite and other rocks of the ophiolite mélange. Tertiary igneous rocks

are Oligocene dacito-andesite lava flows, and Neogene quarztlatite/rhyodacite extrusions and pyroclastic rocks. Eastern basin margin is characterized by Oligocene I-type granitoides Kopaonik and Drenje. The northern border represents Miocene S-type granite Polumir. Sedimentary rocks are mainly Neogene in age and are made of conglomerate, sandstone, three to nine coal seams, coal shale, shale, and marlstone.

The Ibar basin was formed during Miocene large scale extension in the NE Dinaride segment of the Alpine-Carpathian-Dinaride system. The Miocene extension let to exhumation of deep seated core-complexes (e.g. Studenica and Kopaonik core-complex) as well as to the formation of extensional basins in the hanging wall (Ibar Basin). Sedimentation started in the Lower Miocene followed by basin subsidence resulting in formation of an up 1500 m thick sequence. The basin is filled with clastic sediments deposited in alluvial and later in lacustrine phase. The alluvial clastics are represented by breccia, conglomerates, sandstones marlstones and several coal layers. The lacustrine phase is characterized by laminated dolomitic marlstones and shales rarely intercalated with sandstones lenses. The swamp stage cyclically repeated several time, causing formation from three to nine coal seams in the deepest parts of the basin (Jarando). Later post-depositional thermal overprint in the Ibar Basin influenced the higher thermal maturity of OM confirmed by measurement of vitrinite reflectance and organic geochemical composition of OM.

The mean random vitrinite reflectance values in coal samples ranging from the 0.75 %Rr (Progorelica) to 0.90 %Rr (Tadenje) and from 0.63 %Rr to 0.79 %Rr in the Piskanja deposit. Microscopic investigation showed that vitrinite is the prevailing maceral group in coal samples. The most abundant maceral is collodetrinite with variable amount of collotelinite and vitrodetrinite. Content of gelinite and corpogelinite is relatively low. Sporinite and liptodetrinite are the most abundant macerals of the liptinite group, while suberinite, cutinite, resinite and exsudatinite are present in lower and variable amount. The inertinite, mainly inertodetrinite and funginite, are present in low amount. The shale samples are characterised by a high contents of liptinite and variable amount of inertinite and vitrinite. Lamalginite, telalginite, liptodetrinite and sporinite are the most abundant macerals of liptinite group. Content of cutinite, resinite, suberinite, and exsudatinite is low. The highest content of telalginite has been detected in the uppermost sample, indicating a shallow lake environment.

The molecular composition of coal alkane fraction is characterized by a high abundance of n-alkanes of long chain (>n-C27) with odd predominance (CPI 1.06–1.73). The distribution of n-alkane in most of shales show bimodal distribution with maximum at n-C29 and n-C27, which is consistent with higher CPI value (CPI>1) and maceral composition (mixture of alginite and terrestrial liptinite in variable amount).

Hopanes with domination or predominance of C3017α(H)21β(H) hopane, and acyclic isoprenoids (pristane and phytane) are present in considerable amounts in saturated, as well as a series of C32- to C35-benzohopanes in aromatic hydrocarbon, implying higher maturity of OM. The regular steranes are present in lower quantities in coal and in higher quantities in shales, with domination or predominance of C29 5α,14α,17α(H) isomer. Higher content of diasterane, diagenetic products of steroids, detected in shale samples. Methyl steroids with a C30 dinosterol structure, detected in all samples, were considered as biomarkers of dinoflagellates. Higher maturity of coal samples reflects trace amount of monoaromatic steroids and presence of triaromatic steroids and their methylated products. Variable content of monoaromatic and triaromatics steroids could reflect catagenetic stage of maturity of OM.

Diterpenoids, sesquiterpenoids and nonhopanoid triterpenoids are present in low quantities. Highest concentrations of sesquit-

erpenoids and diterpenoids imply higher contribution of gymnosperms over angiosperm in almost all coal samples. Contrary, the highest concentrations of non-hopanoid triterpenoids of the oleanane skeleton and des-A-degraded non-hopanoid triterpenoids over diterpenoids suggest a higher contribution of angiosperm in shales.

The aromatic hydrocarbons include naphthalene, alkyl naphthalenes, phenanthrene, alkyl phenanthrenes, alkyl thiophene, which are the most abundant aromatic biomarkers in almost all coal and some shale samples. Mono- and triaromatic steroids, with alkyl naphthalenes, phenanthrene and alkyl phenanthrenes are the most abundant biomarkers in most of shale samples. Other polycyclic aromatic hydrocarbons (PAH) such as biphenyl, fluorene, fluoranthene, pyrene, chrysene, triphenylene, benz[a]anthracene and their methylated derivatives methylbiphenyl, dimethylbiphenyl, methylfluorene, dimethylfluorene, methylpyrene and methylchrysene are found in almost all samples, and imply catagenetic stage of maturity of OM.

Volcanic activity was an additional factor that gave rise to higher temperature in the shallow crustal levels. It was accompanied by intrusive magmatism represented by Oligocene granitoid of Mt. Kopaonik and Miocene granite of Polumir. In addition, the basin hosts boron mineralization (borates and howlite) and magnesite deposits and that further implies elevated temperatures in this lacustrine system and can indicate a possible role of hydrothermal solutions.

Age of karst sediments in SW Slovenia

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The territory of Slovenian Dinarides (Dinaric Karst) is mainly built of Mesozoic carbonates and Paleogene flysch deposits. There is no evidence of younger marine deposition in the SW part of Slovenia. Due to the missing record it is very difficult to define tectonic, paleoclimatic and other processes for the last 30 million years.

A valuable additional source of data represents karst sediments, especially cave sediments. These can be allochthonous, which are mostly fluvial clastic sediments or autochthonous, for example speleothems.

Systematic research of cave sediments in Slovenian caves in the last 20 years with different dating methods (paleomagnetic studies, U series dating, paleontology, palynology,…) showed that the sediments are much older than was originally assumed, as identified age cover not only the entire period of the Pleistocene but also the Pliocene and even reach into the Miocene.

Distinct phases of massive deposition in caves with as yet still preserved sediments were dated to about 5.4–4.1 Ma (Miocene–Pliocene), 3.6–1.8 Ma (Pliocene) and Quaternary, following the cessation of Miocene deposition in the Pannonian Basin in the central, E and SE Slovenia and post-Messinian evolution in the SW and W Slovenia. These sedimentation phases in underground suggest climatic changes on the surface with possible flood events and/or changes of the tectonic regimes during Neogene and Quaternary.

Regarding chemical denudation rate from 20 m to 50 m/Ma many older caves and cave sediments already no longer exists, but their residues are present on the surface as unroofed caves or bigger accumulation of clastic sediments. Those sediments were once interpreted as remains of rivers deposits, deposited on karst surface during the so called “pre-karst” phase.

However, since the processes of sedimentation in the caves is very complex and strongly influenced by local factors, sediment thickness of profiles usually only a few meters and interrupted by several unconformities, the interpretation of cave sediments and the resulting data of the surface and subsurface processes are very complex. Calibrated data contributed to reconstruction of the speleogenesis, deposition in caves, and indirectly to evolution of karst surfaces and succession of tectonic displacements. From the age of the cave sediments follows that the caves and karstification have to be even older and we can conclude that the evolution of caves in South Slovenia took part within one post-Eocene karstification period.

In the bottom of karst poljes (intramontane basins of External Dinarides) in southern Slovenia prevail Pleistocene sediments, except in the Kočevsko polje where in the bottom are also Miocene sediments. Lake deposits of karst poljes were mainly studied regarding coal deposits in the Kanižarica (Pliocene brown coal) and Kočevje (Miocene, Pliocene brown coal) or regarding hydromelioriation of karst poljes (Pleistocene and Holocene sediments of Planinsko nad Cerkniško polje) in fifties of the last century.

With paleomagnetic methods we were studied two profiles of surface sediments. In Velenje basin we studied sediments of upper part of 1000 thick terrestrial to lacustrine sequence containing thick lignite seam. The whole analysed profile was N polarized, most probably deposited within the Brunhes chron (<780 ka), which is in accordance with general geological data of the area. Studied was also sediment profile at Hrastje north of Novo mesto. The depression was filled with greyish laminated to thin bedded clayey lacustrine deposits with few gastropod shells, plant remains and plant roots. The whole profile was N polarized except the last sample, which was R; pollen analyses and U-series dating of gastropod are still in progress.

In the future it will be necessary to study also the clastic sediments of karst poljes of southern Slovenia get more information on time of deposition, climate changes and tectonic evolution.

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