12th ESSEWECA conference

8th – 9th December 2022

Bratislava, Slovakia

Environmental, Structural & Stratigraphical Evolution of the Western Carpathians

ESSEWECA

Since 1998

Environmental, Structural and Stratigraphical Evolution of the Western Carpathians

Abstract book

COMENIUS UNIVERSITY BRATISLAVA

Faculty of Natural Sciences

doc. Mgr. Natália Hudáčková, PhD.
Mgr. Andrej Ruman, PhD.
doc. RNDr. Michal Šujan, PhD.
Editors

Environmental, Structural and Stratigraphical Evolution of the Western Carpathians

Abstract Book

12th ESSEWECA Conference

8th – 9th December 2022
Bratislava, Slovakia

2022
Comenius University Bratislava

Conference is organized by: *Slovak Geological Society, Bratislava*

The conference is under financial support of the companies
Nafta a.s., EQUIS, spol. s r.o. and BARZZUZ s.r.o.

Scientific guarantee:

Comenius University Bratislava, Faculty of Natural Sciences,
Department of Geology and Paleontology

Cover: Collage of figures published in open access journals by the authors of the conference contributions, named in the technical imprint at the end of the abstract book.

https://stella.uniba.sk/texty/PRIF_esseweca_22.pdf

Publisher: Comenius University Bratislava, 2022

ISBN: 978-80-223-5518-6 (printed version)

ISBN: 978-80-223-5519-3 (online version)

Contents

(page intentionally left blank)

Preface

The scientific board and organizing committee are most honored to cordially welcome guests and presenters to Bratislava, for the 12th ESSEWECA conference, organized on December 8th – 9th 2022, especially after the undesirable four years break due to the COVID pandemics. The plenary and topical sessions are held in the conference room of the Science Park of the Comenius University in Bratislava, Slovakia.

The biannual conference is devoted to environmental, sedimentary, stratigraphic and structural evolution of the Western Carpathians together with the Pannonian domain and related Alpine orogenic zones and it is good opportunity to bring together specialists of neighboring countries to participate and discuss the various geological topics useful for the interregional correlation.

Presentation of new results and ideas concerning the fundamental questions of the structural evolution of the Alpine-Carpathian-Dinaridic orogenic systems during Paleoalpine and Neoalpine evolutionary stages and the tectonic control on the sedimentation and basin development should be the main goal of the talks.

A relationship of the magmatism and tectonics is also one of the critical points of the existing and new models of geodynamic development. A reconstruction of the tectonic evolution of the lithosphere supports the palaeogeographic models of ALCAPA, Tisza-Dacia and other related domains in a micro-continental or continental scale from the Mesozoic to Cenozoic eras.

The 12th ESSEWECA conference volume is devoted to the 70th anniversary of **prof. Michal Kováč**, as we are pleased to celebrate together with our dear colleague. Hence, a special topic of the meeting will be dedicated to the evolution of the Cenozoic basins in the Alpine-Carpathian-Dinaride-Balkan regions and especially in the Pannonian Basin System, in recognition of the excellent geological research and for outstanding contribution to our knowledge, which was achieved by prof. Kováč.

Michal Kováč was born September 11, 1952, in Zlaté Moravce. He studied geology at Charles University in Prague since 1970 and graduated in 1975 under the supervision of Ján Seneš. Following year at the same university, he got the RNDr. title, while working on his Doctoral study at the Geological Institute of the Slovak Academy of Sciences in Bratislava (1975–1980). He was employed at the Geological Institute of the Slovak Academy of Sciences in Bratislava as the Junior and as the Senior research worker, respectively, between the years 1981–1985 and 1986–1994. Since 1994 to 2003 he started his first period as a head of the Department of Geology and Paleontology, Faculty of Natural Sciences, Comenius University in Bratislava. He obtained the titles Doc. – associate professor (1996), DrSc. – Doctor of Science (2000) and Prof. – full professor (2001) in these years. During the following years (2003–2011), he acts as the Vice dean at Faculty of Natural Sciences at the Comenius University in Bratislava. Right after the second and third periods of his leading the Department of Geology and Paleontology at our university followed and last up till now.

Michal Kováč is an expert in sedimentology and sequence stratigraphy. During his ongoing career he has been solving questions of palaeogeography and geodynamics of the Western Carpathians and adjacent parts of the Pannonian Basin area during the Neogene and Quaternary and Cenozoic in general. He has built a scientific team directing research into Neogene basins with a focus on sedimentology, biostratigraphy, sequential stratigraphy, tectonics, interpretation of geophysical data, geomorphology and for years he has been its driving force. Priority in his scientific direction within the framework of many Slovak and international projects plays the Miocene paleogeography in the Central European context, its high-resolution stratigraphy and paleoenvironmental and paleoclimatic changes. The footprint of Michal Kováč in the field of Cenozoic basin research is evident and well-known as shown by the outputs from the databases with more than 3,300 citations to his more than 120 published scientific papers and international conferences hosted around 100 of his scientific presentations. In the years 2000–2006 he was a member of the Executive committee of the European Science Foundation project – EEDEN: Evolution and Ecosystem Dynamics of Euroasian Neogene and the head of the Scientific-technical project of the Ministry of Education of the Slovak Republic: Ecosystems of the Late Miocene, Pliocene, and Quaternary – indicators of the age and climatic changes. During the years 2007–20011 he was a national representative for the European Science Foundation project – EUROCORES – TOPOEUROPE.

Michal Kováč is a member of inaugural, habilitation commissions and of several professional geological societies, scientific and testing boards and commissions, e.g., Regional Committee on Mediterranean Neogene Stratigraphy by International Union of Geological Sciences more than 25 years. He supervised almost 20 doctoral students and numerous master students. These are official records, but he has been willing to consult and express his professional opinion whenever colleagues and students ask him to.

Between his significant cooperation worth mentioning are those with Czech colleagues, e.g., professor Brzobohatý and doctor Cícha on the regional stage Karpatian; with Austrian colleagues e.g., professor Steininger on the famous Popov´s work of the Lithological-Paleogeographic maps of Paratethys. Recently, he is a proponent and supporter of cooperation between Slovak (Dr. Šujan), Hungarian (Assoc. Prof. Sztanó, Dr. Magyar) and French (Dr. Braucher) professionals on solving Lake Panon evolution using up-to-date radionuclide methods, sedimentology and biostratigraphy.

Awards presented to prof. Michal Kováč

2018 - Slovak Geological Society Prize – for most important scientific paper between 2016 – 2018

2017 - Silver Medal of the Comenius University for outstanding contribution of the Western Carpathian Cenozoic research, European-level Science school foundation and for the successful presentation of the Comenius University abroad, Comenius University in Bratislava

2017 - Dionýz Štúr Prize, category "Personality" – for excellent lifetime contribution to geology, State Geological Institute of Dionýz Štúr

2016 - Bohuslav Cambel Medal – for outstanding scientific contributions to research in geosciences, The Earth Science Institute of the Slovak Academy of Sciences

2016 - Ján Pettko Prize – for promoting the Slovak geology abroad and for citation impact (H-index 19, SCOPUS), National Geological Committee of Slovakia

2015 - Silver Medal of Comenius University to Excellence Team – Geodynamic Development of the Western Carpathians (principal investigator – prof. RNDr. Michal Kováč, DrSc.), Comenius University in Bratislava

2013 - Memorial Medal of Geological Institute of the Slovak Academy of Sciences – for contribution to, and development of geosciences, Geological Institute of the Slovak Academy of Sciences in Bratislava

2012 - Dimitrij Andrusov Medal – for contribution to the Western Carpathian geology, Faculty of Natural Sciences, Comenius University in Bratislava

2010 - Honorable Mention – for extraordinary results and long-lasting contribution to environmental care, Ministry of Environment of the Slovak Republic

2009 - Honorable Mention – in recognition of his fundamental contribution to the understanding of the Paratethys geodynamics in 13th Congress RCMNS, Regional Committee on Mediterranean Neogene Stratigraphy

2005 - Ján Slávik Medal – for extraordinary contribution to the understanding of the Western Carpathian geology and long-lasting contribution to Slovak Geological Society activities, Slovak Geological Society

2005 - Slovak Geological Society Prize – for most important scientific paper between 2001 – 2004 - Kováč, M., Bielik, M., Hók, J., Kováč, P., Labák, P., Moczo, P., Plašienka, D., Šefara, J. & Šujan, M., 2002: Seismic activity and neotectonic evolution of the Western Carpathians (Slovakia). In: Cloetingh, S.A.P.L., Horváth, F., Bada, G. & Lankreijer, A.C. (Eds.): Neotectonics and seismicity of the Pannonian Basin and surrounding orogens. EGS Stephan Mueller Special Publication, 3, 167–184. Slovak Geological Society

2002 - Memorial Medal of 100 years of the Hurbanovo Observatory – for contribution to seismic research in Slovakia, Division of Geophysics, Earth Science Institute, Slovak Academy of Sciences

2002 - Memorial Medal of 240 years of the Technological University in Slovakia – for contribution to Slovak Science, Slovak Technological University in Bratislava

2000 - Memorial Medal of 60 years of the Faculty of Natural Sciences, Comenius University in Bratislava – for extraordinary effort and excellent results, Faculty of Natural Sciences, Comenius University in Bratislava

Most important publications of prof. Michal Kováč

Popov, S.V., Rögl, F., Rozanov, A.Y., Steininger, F.F., Shcherba, I.G. & Kováč, M. 2004. Lithological-paleogeographic maps of paratethys. *CFS Courier Forschungsinstitut Senckenberg*, 250, 1–46.

Csontos, L., Nagymarosy, A., Horváth, F. & Kováč, M. 1992. Tertiary evolution of the Intra-Carpathian area: A model. *Tectonophysics*, 208, 221–241.

Kováč, M., Andreyeva-Grigorovich, A., Bajraktarević, Z., Brzobohatý, R., Filipescu, S., Fodor, L., Harzhauser, M., Nagymarosy, A., Oszczypko, N., Pavelić, D., Rögl, F., Saftić, B., Sliva, L. & Studencka, B. 2007. Badenian evolution of the Central Paratethys Sea: Paleogeography, climate and eustatic sea-level changes. *Geologica Carpathica*, 58, 579–606.

Kováč, M., Baráth, I., Harzhauser, M., Hlavatý, I. & Hudáčková, N. 2004. Miocene depositional systems and sequence stratigraphy of the Vienna Basin. *CFS Courier Forschungsinstitut Senckenberg*, 246, 187–212.

Kováč, M., Kráľ, J., Márton, E., Plašienka, D. & Uher, P. 1994. Alpine uplift history of the central western Carpathians: geochronological, paleomagnetic, sedimentary and structural data. *Geologica Carpathica*, 45, 83–96.

Meulenkamp, J.E., Kováč, M. & Cicha, I. 1996. On Late Oligocene to Pliocene depocentre migrations and the evolution of the Carpathian-Pannonian system. *Tectonophysics*, 266, 301–317.

Lankreijer, A., Kováč, M., Cloetingh, S., Pitoňák, P., Hlôška, M. & Biermann, C. 1995. Quantitative subsidence analysis and forward modelling of the Vienna and Danube basins: thin-skinned versus thick-skinned extension. *Tectonophysics*, 252, 433–451.

Kováč, M., Hudáčková, N., Halásová, E., Kováčová, M., Holcová, K., Oszczypko-Clowes, M., Báldi, K., Less, G., Nagymarosy, A., Ruman, A., Klučiar, T. & Jamrich, M. 2017. The Central Paratethys palaeoceanography: A water circulation model based on microfossil proxies, climate, and changes of depositional environment. *Acta Geologica Slovaca*, 9, 75–114.

Kováč, M., Márton, E., Oszczypko, N., Vojtko, R., Hók, J., Králiková, S., Plašienka, D., Klučiar, T., Hudáčková, N. & Oszczypko-Clowes, M. 2017. Neogene palaeogeography and basin evolution of the Western Carpathians, Northern Pannonian domain and adjoining areas. *Global and Planetary Change*, 155, 133–154.

Kováč, M., Plašienka, D., Soták, J., Vojtko, R., Oszczypko, N., Less, G., Ćosović, V., Fügenschuh, B. & Králiková, S. 2016. Paleogene palaeogeography and basin evolution of the Western Carpathians, Northern Pannonian domain and adjoining areas. *Global and Planetary Change*, 140, 9–27.

Understanding the variability of authigenic $^{10}Be/^{9}Be$ ratio: An example from deltaic to offshore facies of the Slanicul de Buzau section, Romania

KISHAN AHERWAR[1], MICHAL ŠUJAN[1], KATARÍNA ŠARINOVÁ[2], RÉGIS BRAUCHER[3], ARJAN DE LEEUW[4], ANDREJ CHYBA[5], ANTON MATOSHKO[6], PETER UHLÍK[2], BARBARA RÓZSOVÁ[1] and ASTER TEAM[3]

1 – Department of Geology and Paleontology, Faculty of Natural Sciences, Comenius University in Bratislava, Ilkovičova 6, 842 15 Bratislava, Slovak Republic; e-mail: kishanaherwar2@gmail.com

2 – Department of Mineralogy and Petrology, Faculty of Natural Sciences, Comenius University in Bratislava, Ilkovičova 6, 842 15 Bratislava, Slovak Republic

3 – Aix-Marseille Univ., CNRS-IRD-INRAE-Collège de France, UM 34 CEREGE, Technopôle de l' Environnement Arbois- Méditerranée, BP80, 13545 Aix-en-Provence, France

4 – ISTERRE, University Grenoble Alpes, Grenoble, France

5 – Institute of Chemistry, Slovak Academy of Sciences, Dúbravská cesta 9, 845 38 Bratislava, Slovak Republic

6 – Palaeomagnetic Laboratory 'Fort Hoofddijk', Faculty of Geosciences, Utrecht University, The Netherlands

The use of authigenic $^{10}Be/^{9}Be$ ratio is already now being couple of times used since last few decades to date the sediment from range of 0.2 to 14 Ma owing to the 1.387±0.012 Ma half-life of radioactive nuclei ^{10}Be. Even though the method has not been used very extensively with only few publications available, it seems to provide promising results e.g., Lebatard et al. (2008, 2010) and Šujan et al. (2016, 2020). Determination of initial authigenic $^{10}Be/^{9}Be$ ratio in this dating method becomes a challenging task because of different origin of both isotopes, since ^{9}Be is derived from weathering and erosion of rock massif and meteoric cosmogenic radionuclide ^{10}Be is produced in the atmosphere. As demonstrated by Wittmann et al. (2017) and Kong et al. (2021) the ratio $^{10}Be/^{9}Be$ varies from river delta to continental slope and distal oceanic settings. However, study focused on the effect of sediment source proximity on the authigenic $^{10}Be/^{9}Be$ in an epicontinental basin is missing and our work is an attempt to shed light on this area to improve the applicability of the method.

In order to understand the variability in initial authigenic $^{10}Be/^{9}Be$ ratio, we considered Slanicul de Buzau section form Dacian basin (Romania) of known age based on magnetostratigraphy. The beryllium isotopic ratio was measured in 28 samples from the section of the Pontian age which marks phases of regression followed by a transgression. The initial ratios in samples were back calculated using the measured isotopic ratio in samples and magnetostratigraphic age (~6.1 – 5.3 Ma) (Matoshko et al., in prep.). As this section is expected to experience progradation of a shelf slope (4th order cycle) it provides a good opportunity to observe how the change in proximity affects the authigenic ratio. The result indicates a 4-fold increase in the initial ratio with a value of $\sim 1.7\times10^{-9}$ for deltaic succession to $\sim 3.1\times10^{-9}$ for shelfal unit with reaching highest value of $\sim 7.1\times10^{-9}$ for offshore unit.

Two early Pliocene deltaic parasequences D and E of known ages ~4.45 Ma and ~4.43 Ma respectively from magnetostratigraphy were also sampled. 19 samples from these parasequences have low variability in initial $^{10}Be/^{9}Be$ ratio from distal to proximal facies. The

results from these parasequences indicates that, in case of high frequency cycles (parasequences) the sediment source proximity does not affects the authigenic $^{10}Be/^{9}Be$ ratio. Some outlier appearing in samples from these parasequences in lower delta front also exhibits higher content of smectite, carbonates and iron, which points to assumption that these outliers must have been affected by post depositional processes, which took place during phases of condensed deposition.

The study suggests that variability of initial authigenic $^{10}Be/^{9}Be$ ratio might be predicted in case of 4th or higher order cycle and in case of high frequency cycle (e.g., parasequences) the initial ratio is not much variable. However, considering other parameters for example knowing the sedimentation rate (which were assumed stable in this study) might further improve the understanding in variability.

Acknowledgement: This project was supported by the Slovak Research and Development Agency under the contract No. APVV-20-0120.

References:

Kong, W., Zhou, L. & Asterteam 2021. Tracing Water Masses and Assessing Boundary Scavenging Intensity With Beryllium Isotopes in the Northern South China Sea. *Journal of Geophysical Research: Oceans*, 126, e2021JC017236.

Lebatard, A.-E., Bourlès, D. L., Braucher, R., Arnold, M., Duringer, P., Jolivet, M., Moussa, A., Deschamps, P., Roquin, C. & Carcaillet, J. 2010. Application of the authigenic $^{10}Be/^{9}Be$ dating method to continental sediments: reconstruction of the Mio-Pleistocene sedimentary sequence in the early hominid fossiliferous areas of the northern Chad Basin. *Earth and Planetary Science Letters*, 297, 57–70.

Lebatard, A.-E., Bourlès, D. L., Duringer, P., Jolivet, M., Braucher, R., Carcaillet, J., Schuster, M., Arnaud, N., Monié, P. & Lihoreau, F. 2008. Cosmogenic nuclide dating of Sahelanthropus tchadensis and Australopithecus bahrelghazali: Mio-Pliocene hominids from Chad. *Proceedings of the National Academy of Sciences*, 105, 3226–3231.

Šujan, M., Braucher, R., Kováč, M., Bourlès, D. L., Rybár, S., Guillou, V. & Hudáčková, N. 2016. Application of the authigenic $^{10}Be/^{9}Be$ dating method to Late Miocene–Pliocene sequences in the northern Danube Basin (Pannonian Basin System): Confirmation of heterochronous evolution of sedimentary environments. *Global and Planetary Change*, 137, 35–53.

Šujan, M., Braucher, R., Tibenský, M., Fordinál, K., Rybár, S. & Kováč, M. 2020. Effects of spatially variable accommodation rate on channel belt distribution in an alluvial sequence: Authigenic $^{10}Be/^{9}Be$ -based Bayesian age-depth models applied to the upper Miocene Volkovce Fm.(northern Pannonian Basin System, Slovakia). *Sedimentary Geology*, 397, 105566.

Wittmann, H., Von Blanckenburg, F., Mohtadi, M., Christl, M. & Bernhardt, A. 2017. The competition between coastal trace metal fluxes and oceanic mixing from the $^{10}Be/^{9}Be$ ratio: Implications for sedimentary records. *Geophysical Research Letters*, 44, 8443–8452.

In the search of the Jurassic – Cretaceous boundary in the lime kilns of Zengővárkony, Mecsek Mountains, Hungary

RICHÁRD GYULA ALBRECHT

Department of Geology and Meteorology, Institute of Geography and Earth Sciences, Faculty of Sciences, The University of Pécs, 6 Ifjúság útja, H-7624, Pécs (Hungary)

Appointing the Jurassic – Cretaceous boundary is still a shortcoming of the modern stratigraphy. Although there are numerous strata around the globe, which provides decent scientific results of various stratigraphical methods, there is still no internationally accepted GSSP (Global Boundary Stratotype Section and Point) between this two Period of the Phanerozoic. A new method of determining the J/K boundary was introduced by Slovakian scientist, (Kowal-Kasprzyk & Reháková, 2019), which is based on the morphometric analysis of loricae of the genus *Calpionella*.

This new method was tested on the Upper Tithonian – Lower Berriasian limestone deposits in Zengővárkony, Hungary. The studied section is a 3 m high, artificially unearthed outcrop in the western part of the bigger quarry at the lime kilns. 50 thins sections were prepared from the 16 sample points of the outcrop, with the following microfauna: *Calpionella alpina, C. elliptalpina, C. grandalpina, Crassicollaria brevis, C. colomi, C. intermedia, C. massutiniana, C. parvula, Tintinnopsella carpathica* and *T. remanei*. Based on the Calpionellids the lower part of the strata belongs to the Upper Tithonian Crassicollaria Zone, while the upper part belongs to the Lower Berriasian Calpionella Zone. Close to the top of the section, there is a visible discordance, hiatus in the strata, which corresponds to the earlier observations from the territory. Most of the earlier researchers (summarized in Nagy, 1967) were on the opinion, that the J/K boundary was not present in the lime kilns, due the erosion or interrupted deposition.

While there is a quite diverse *Crassicollaria* fauna in the lower part of the section, it changes, and they all disappear except the *Cr. massutiniana*. With circa 0,85 meter above this observation (but still below the hiatus), a rapid increase can be observed both in relative and absolute number of the *C. alpina* specimens. The *C. alpina* specimens from the area of the explosion were measured according to the method of Kowal-Kasprzyk and Reháková (2019). After the measurements, it can be stated, that the chosen part of the section does not correspond with the Crassicollaria Zone and neither with the Alpina Subzone, it appears as a transition between them, and shows resemblance to the assemblages from the J/K boundary samples of Kowal-Kasprzyk and Reháková. With this new information we can conclude, that the J/K boundary is not “lost” in the hiatus, it is in the lower part of the continuous section.

With continuation of this research, the more precise determination of the boundary is expected in this section.

Acknowledgement: The base of this research was supported by the project 99öu02 of the Österreichische-Ungarische Aktion Gesellschaft (Osztrák-MagyarAkció Alapítvány).

References:

Nagy, I. 1967. A felsőjura képződmények és a kréta vulkanitok viszonya a Mecsekben. *A Magyar Állami Földtani Intézet Évi Jelentése az 1965. évről*, 149–168.

Kowal-Kasprzyk, J., & Reháková, D., 2019. A morphometric analysis of loricae of the genus Calpionella and its significance for the Jurassic/Cretaceous boundary interpretation. *Newsletters on Stratigraphy*, 52, 1, 33–54.

Nannoplankton biostratigraphy and paleoecology of the Paleocene formations in K/Pg section near Žilina

SILVIA ANTOLÍKOVÁ[1] and JÁN SOTÁK[2,3]

1 – The Earth Science Institute of the Slovak Academy of Sciences, Dúbravská cesta 9, P.O.BOX, 106, Bratislava, 840 05 Bratislava, Slovak Republic; e-mail: antolikovasilvia@gmail.com

2 – The Earth Science Institute of the Slovak Academy of Sciences, Ďumbierska 1, 974 11, Banská Bystrica Slovak Republic

3 – Faculty of Education, Catholic University in Ružomberok, Hrabovská cesta 1, 03 401 Ružomberok, Slovak Republic

Upper Cretaceous/Paleocene sediments of the Žilina section were investigated based on calcareous nannoplankton. They belong to Hradisko and Hričovské Podhradie Fms, which occur in overturned position of Maastrichtian marls (0 – 12.1 m) above Paleocene claystones (12.2 – 65 m). The nannofossils from 31 samples were studied for providing a biostratigraphic and paleoecological evaluation based on the NP zonation by Martini (1971), and latest correlations by Farinaci and Howe (2022) and Young and Bown (2022).

The assemblage of calcareous nannofossils consists of cca 50 % reworked Mesozoic species and cca 50 % Paleocene autochthonous species. The nannofossils reworked from the Mesozoic formations nannoassemblage comprise of species: *Arkhangelskiella maastrichtiensis*, *Arkhangelskiella cymbiformis*, *Broinsonia matalosa*, *Cretarhabdus conicus Micula staurophora*, *Microrhabdus matalosa*, *Microrhabdulus undosus*, *Maurinolithus lesliae Retecapsa crenulata*, *Watznaueria barnesae*.

Autochthonous nannoflossils belongs to Paleocene species, comprising of 34 taxa with majority of *Coccolithus pelagicus* (average 47 %), *Ericsonia media*/*Ericsonia subpertusa* (average 19 %/3 %), and *Neochiastozygus concinnus* (average 8 %). The samples also reveal an abundance of calcareous dinoflagellate *Thoracospahaera sp*. (average 13 %). Other Paleocene species like *Umbilicosphaera jordanii*, *Chiasmolithus danicus*, *Toweius selandianus*, *Chiasmolithus edentulus*, *Pontosphaera plana*, *Neochiastozygus concinnus*, *Zeugrhabdotus embergeri*, *Sphenolithus moriformis*, *Zeugrhabdotus sigmoides*, *Chiasmolithus bidens*, *Chiasmolithus nitidus*, *Fasciculithus clinatus* are also present.

Calcareous nannofossils were used to NP zonation according to Martini (1971):

Danian NP 2 Zone based on species *Coccolithus pelagicus* (interval from 12.2 m)

Danian NP 3 Zone based on species *Ericsonia subpertusa* (interval from 12.4 m)

Selandian NP 5 Zone based on species *Ericsonia media* (interval from 14.9 m)

Selandian NP 6 Zone based on species *Fasciculithus involutus* (interval from 38.0 m)

Thanetian NP 9 Zone based on species *Chiasmolithus solitus*, *Zygrhablithus bijugatus* (from 49.7 to 62.0 m)

Dominant presence of the species *C. pelagicus* associated with *Toweius* sp. is typical for Paleocene formations prior to the PETM event, although *Toweius* sp. is very rare in our samples. The PETM event culminated by rapid decrease of *C. pelagicus* (Gibbs et al. 2006).

Co-occurrence of *C. pelagicus* with *E. subpertusa* dominated during Danian (Kasem et al. (2022). These species are considered to represent cold-water taxa, on the contrary, that during the Danian were transient warm-water marine conditions. Accordingly, *C. pelagicus* is regarded as warm-water and oligotrophic species (Tremolada and Bralower 2004), but these coccolits are also interpreted as eutrophic species (Aubry 1998).

Calcareous nannofossils like *C. pelagicus*, *Ericsonia*, *Neochiastozygus* and *Fasciculithus* belong to species with K-strategy. Therefore, they paleoecology indicate oligo- to mesotrophic and deep-water conditions (Höll et al. 1998). Similarly, an increased occurrence of the calcareous dinoflagellate *Thoracospahaera sp*. indicates a reduced productivity, that is probably related to relatively stratified, oligotrophic oceanic conditions.

Nannofossil assemblage of the Žilina section consists of Paleocene species, but not those from the PETM period. Beside sporadic cold-water species, the association is dominated by warm-water and oligotrophic taxa.

Acknowledgement: The study was supported by the projects APVV-20-0079 and VEGA 2/0013/20.

References:

Farinacci, A. & Howe, R.W. 1969–2022. The Farinacci & Howe Catalog of Calcareous Nannofossils. Vols 1-26. Accessed online at: mikrotax.org/Nannotax3/index.php?id=50001

Aubry, M.-P. 1998. Early Paleogene calcareous nannoplankton evolution: A tale of climatic amelioration. *In:* Aubry, M.-P., et al. (Eds.): *Late Paleocene–early Eocene climatic and biotic events in the marine and terrestrial records.* New York, Columbia University Press, 158–203.

Höll, C., Zonneveld, K.A.F. & Willems, H. 1998. On the ecology of calcareous dinoflagellates: The Quaternary Eastern Equatorial Atlantic. Marine *Micropaleontology*, 33, 1–2, 1–25.

Kasem, A.M., Faris, M., Jovane, L., Ads, T.A., Frontalini, F. & Zaky, A.S. 2022. Biostratigraphy and Paleoenvironmental Reconstruction at the Gebel Nezzazat (Central Sinai, Egypt): A Paleocene Record for the Southern Tethys. *Geosciences* 2022, 12, 96, 1–22.

Martini, E. 1971 : Standard Tertiary and Quaternary Calcareous Nannoplankton Zonation. *Proceedings of the 2nd Planktonic Conference,* Roma, 1970, 739–785.

Gibbs, S.J., Bralower, T.J., Bown, P.R., Zachos, J.C. & Bybell, L.M. 2006. Shelf and open-ocean calcareous phytoplankton assemblages across the Paleocene-Eocene Thermal Maximum: Implications for global productivity gradients. *Geology*, 34, 4, 233–236.

Tremolada, F. & Bralower, T.J. 2004. Nannofossil assemblage fluctuations during the Paleocene–Eocene Thermal Maximum at Sites 213 (Indian Ocean) and 401 (North Atlantic Ocean): palaeoceanographic implications. *Marine Micropaleontology*, 52. 107–116.

Young, J.R., Bown P.R. & Lees J.A. 1998 – 2022. Nannotax3 website. International Nannoplankton Association. Accessed 21 Apr. 2022. URL: www.mikrotax.org/Nannotax3

Special preparation procedure for miliolids with preservation problem for Laser Ablation Inductively Coupled Plasma Mass Spectrometry analyses

JAROSLAVA BABEJOVÁ-KMECOVÁ[1], EDIT KIRÁLY[2], KATALIN BÁLDI[3] and NATÁLIA HUDÁČKOVÁ[1]

1 – Comenius University, Faculty of Natural Sciences, Department of Geology and Paleontology, Ilkovičova 6, 84215 Bratislava, Slovak Republic; e-mail: kmecova45@uniba.sk

2 – Mining and Geological Survey of Hungary, H 1143 Budapest, Hungary

3 – Eötvös Loránd University, Faculty of Natural Sciences, Department of Physical and Applied Geology, 1117 Pázmány Péter St 1/c, Budapest, Hungary

The past distribution of benthic foraminifera is sometimes enigmatic, where the cause of dominance of taxa is not well known. In order to learn more of depositional environment and the limiting factors in the past, chemical analyses are needed.

The calcareous fossil foraminiferal tests preserve chemical signals by binding different elements in equilibrium with the surrounding water, though the phenomenon of vital effect is also known (Lea 1999; Hönisch et al. 2012). Stable isotopes ($\delta^{18}O$, $\delta^{13}C$) and the ratios of trace elements (metal/calcium) are the proxies used most frequently. The ratios of Mn/Ca, Mg/Ca, Ba/Ca, Sr/Ca, and Cd/Ca in foraminifera calcite mainly controlled by dissolved oxygen concentration and salinity of seawater (Meier et al. 2011). The Mn/Ca ratio is considered the best proxy for hypoxic condition (Koho et al. 2017; Brinkmann et al. 2021), Ba/Ca for salinity and freshwater discharge (Lea & Boyle 1991; Groeneveld et al. 2018) and Mg/Ca is a temperature proxy (Barker et al. 2005; Sadekov et al. 2005).

Our samples come from the Neogene foraminiferal assemblage of Central Paratethys (Malacky location, well MZ 102) already studied (Babejová-Kmecová et al. 2022) and dominated by miliolids (*Articulina problema, Miliolinella subrotunda, Pseudotriloculina consobrina, Varidentella rotunda*) from the "miliolid horizons" (Hudáčková & Koubová 2010). The aim was to find the best preparational method for the porcelaneous foraminifera tests for the subsequent geochemical analysis. To achieve this, the miliolid tests had to be imbedded into resin, polished, and measured by LA-ICP MS, where standard methodology did not work, as fragile miliolids imbedded into the resin when polished, crumbled, and fall out. From each sample approximately 10-15 tests of foraminifera were picked and separated according to species. The tests were sonicated in methanol bath for approximately 10-15 min and rinsed twice in distilled water baths for 15 min. Dried individuals had been cold mounted by epoxy resin and hardener Araldite® AY 103-1. The curing period took 24-30 hours in the oven and constant temperature of 40 °C. Dried and hardened resin blocks were sanded at 600 grit, just enough for foraminiferal tests to lay few μm under the resin surface. The methodology established in the frame of the here presented work seems to be the best preparation technique for fragile porcelaneous (miliolid) tests of foraminifera.

Acknowledgments: This research was supported by the Slovak Research and Development Agency under contracts No. APVV-20-0079, VEGA-2/0169/19, APVV-20-0120 and VEGA-2/0013/20.

References:

Babejová-Kmecová, J., Plašienková, I., Sliva, Ľ., Halásová, E. & Hlavatá Hudáčková, N. 2022. From dysoxic sea to hypersaline lagoon: paleoenvironmental changes on the Badenian/Sarmatian boundary (borehole MZ102; Vienna Basin). *Acta Geologica Slovaca*, 14, 1, 57–70.

Barker, S., Cacho, I., Benway, H.M. & Tachikawa, K. 2005. Planktonic foraminiferal Mg/Ca as a proxy for past oceanic temperatures: A methodological overview and data compilation for the Last Glacial Maximum. *Quaternary Science Reviews*, 24, 821–834.

Brinkmann, I., Ni, S., Schweizer, M., Oldham, V.E., Quintana Krupinski, N.B., Medjoubi, K., Somogyi, A., Whitehouse, M.J., Hansel, C.M., Barras, C., Bernhard, J.M. & Filipsson, H.L. 2021. Foraminiferal Mn/Ca as Bottom-Water Hypoxia Proxy: An Assessment of Nonionella stella in the Santa Barbara Basin, USA. *Paleoceanography and Paleoclimatology*, 36, 11, 1–21.

Groeneveld, J., Filipsson, H.L., Austin, W.E.N., Darling, K., McCarthy, D., Krupinski, N.B.Q., Bird, C. & Schweizer, M. 2018. Assessing proxy signatures of temperature, salinity, and hypoxia in the Baltic Sea through foraminifera-based geochemistry and faunal assemblages. *Journal of Micropalaeontology*, 37, 2, 403–429.

Hönisch, B., Ridgwell, A., Schmidt, D. N., Thomas, E., Gibbs, S.J., Sluijs, A., Zeebe, R., Kump, L., Martindale, R.C., Greene, S.E. 2012. The geological record of ocean acidification. *Science*, 335, 6072, 1058–1063.

Hudáčková, N., Koubová, I. & Zlinská, A., 2010. Lower Sarmatian foraminifera from marginal marine environments in the Malacky vicinity (Vienna Basin). *Geologické výzkumy na Moravě a ve Slezsku*, 17, 1–2.

Koho, K.A., de Nooijer, L.J., Fontanier, C., Toyofuku, T., Oguri, K., Kitazato, H. & Reichart, G.-J. 2017. Benthic foraminiferal Mn/Ca ratios reflect microhabitat preferences. *Biogeosciences*, 14, 3067–3082.

Lea, D.W. & Boyle, E.A. 1991. Barium in planktonic foraminifera, *Geochimica et Cosmochimica Acta*, 55, 3321–3331.

Lea, D.W. 1999. Trace elements in foraminiferal calcite. *In*: Sen Gupta, Barun K. (Ed): *Modern Foraminifera*. Kluwer Academic Publishers, Dordrecht, The Netherlands, 259-277.

Meier, H.M., Andersson, H.C., Eilola, K, Gustafsson, B.G., Kuznetsov, I., Müller-Karulis, B., Neumann, T. & Savchuk, O.P. 2011. Hypoxia in future climates: A model ensemble study for the Baltic Sea. *Geophysical Research Letters*, 38, L24608.

Sadekov, A.Y., Eggins, S.M. & de Deckker, P. 2005. Characterization of Mg/Ca distributions in planktonic foraminifera species by electron microprobe mapping. *Geochemistry, Geophysics, Geosystems*, 6: Q07012.

Climate change affecting the intraspecific variability of Saturnalidae, (Radiolaria) in the pre- and post-OAE2 periods

MARTA BĄK[1] and KRZYSZTOF BĄK[2]

1 – Faculty of Geology, Geophysics, and Environmental Protection, AGH-University of Science and Technology, Mickiewicza Av. 30, 30-059 Kraków, Poland; e-mail: martabak@agh.edu.pl

2 – Faculty of Exact and Natural Sciences, Pedagogical University of Krakow, Podchorążych St.,30-084 Kraków, Poland

Saturnalids belong to the Radiolaria group, the siliceous skeletons of which are adapted to support the extensive cytoplasm and cultivate symbionts. For this reason, the Cretaceous representatives of the saturnalids are considered to be forms associated with the rather oligotrophic ocean surface waters (Bąk 2011). In studies presented here, the skeleton sizes (diameters of rings) of species that belong to the family Saturnalidae were measured and compared from the Scaglia Bianca pre- and post-OAE2 deposits in the Umbria Marche region of Italy.

All specimens from the sediments preceding the OAE2 were relatively small in size. This could indicate that these specimens lived in surface waters with limited conditions favorable their development, and prevailing periods of intense upwelling. On the other hand, in sediments above the Bonarelli Level (OAE2), all species belonging to the saturnalids are much larger. This most likely indicates longer periods of sustained strong oceanic stratification, that supported their growth, with prolonged deep thermocline stabilization in the western Tethys region. Such episodes of prolonged stagnation in the vertical circulation in the water column may have been associated with periods of dry and hot climatic oscillations at that time.

Acknowledgement: Support for data reported here was provided by from the National Science Centre, Poland, under project 2021/41/B/ST10/02994.

References:

Bąk, M. 2011. Tethyan radiolarians at the Cenomanian–Turonian anoxic event from the Apennines (Umbria-Marche) and the Outer Carpathians: Palaeoecological and palaeoenvironmental implications. *Studia Geologica Polonica*, 134, 7–279.

Carbon-isotope stratigraphy and palaeoceanographic significance of the mid-Cretaceous deep-water sediments from marginal part of the Western Tethys

MARTA BĄK[1], KRZYSZTOF BĄK[2] and ZBIGNIEW GÓRNY[1]

1 – Faculty of Geology, Geophysics, and Environmental Protection, AGH-University of Science and Technology, Mickiewicza Av. 30, 30-059 Kraków, Poland; e-mail: martabak@agh.edu.pl

2 – Faculty of Exact and Natural Sciences, Pedagogical University of Krakow, Podchorążych St.,30-084 Kraków, Poland; e-mail: krzysztof.bak@up.krakow.pl

Chemostratigraphic ($\delta^{13}C_{org}$) and biostratigraphic data from a 46-m-long, sedimentary deep-water succession exposed at the Barnasiówka-Jasienica section of the marginal Silesian Basin of the Western Tethys allowed identified of several carbon isotope excursions, containing the OAE1d in the latest Albian and MCE Ia, MCE Ib, and ?MCE II during the middle Cenomanian (Bąk et al. 2022). The OAE1d represents here the older part of the Albian–Cenomanian Boundary Interval coinciding with enhanced accumulation of organic-rich clays, distinguished in this succession as the Alternans Level. Most of organic matter supplied to the Silesian (marginal) Basin during that time came from the land.

The whole succession is represented by flysch facies, where hemipelagic shales are intercalated with turbidites including fine-grained sandstones and siltstones. They contain a large amount of biogenic material, enriched in sponge spicules (Bąk et al. 2015; Górny et al. 2022). This biogenic input took place during the latest Albian through the middle Cenomanian and was controlled by third-order sea level fluctuations (Bąk et al. 2022). The chemostratigraphic data allow precise determination of the beginning and end of the mass redeposition of biogenic material from the European peri-Tethyan shelf which lasted ca 4.5 Ma, with an average sedimentation rate of ∼5 mm kyr^{-1}. Its beginning took place at an interval that corresponds to the base of OAE1d as a third-order record of a global regressive event – the KAl8 event *sensu* Haq (2014). The end of this palaeoceanographic phenomenon occurred between MCE Ib and MCE II in the middle Cenomanian. This interval was correlative to sea level fall during the KCe3 eustatic event. The subsequent middle–Late Cenomanian eustatic cycles (KCe4 and KCe5) were not marked by abundant resedimentation of sponge spicules due to prominent first-order sea level transgression that continued into Early Turonian; this limited the development of sponges on peri-Tethyan shelves.

Acknowledgement: Support for obtaining the carbon-isotope data reported here was provided by funds to K. Bąk from the National Science Centre, Poland, under project 2016/23/B/ST10/01731. Thin section slides of microfacies and field studies were collected with the assistance of the AGH University of Science and Technology and Pedagogical University of Krakow under projects WGGiOŚ-KGOiG no.16.16.140.315 (by M. Bąk) and UP-FENS no WPBU/2022/04/00194 (by K. Bąk).

References:

Bąk, M., Bąk, K. & Górny, Z. 2022. Timing of mass redeposition of sponge spicules from the peri-Tethyan shelf into the deep Carpathian basin and their relation to mid-Cretaceous global sea level changes. *Geological Society of America Bulletin*, https://doi.org/10.1130/B36178.1

Bąk, M., Górny, Z. & Bąk, K. 2015. Sponge growth on the Cenomanian carbonate shelves of the Carpathian Basin: a record from spicule-rich turbidites. *Bulletin of Geosciences*, 90, 3, 651–666.

Górny, Z., Bąk, M., Bąk, K. & Strzeboński, P.A. 2022. Planktonic biota constituents responses to global sea-level changes recorded in the uppermost Albian to middle Cenomanian deep-water facies of the Outer Carpathians. *Minerals*, 12, 2, Article 152.

Haq, B. 2014. Cretaceous eustasy revisited. *Global and Planetary Change*, 113, 44–58.

New U-Pb zircon geochronological data of Neogene andesites (Pieniny Klippen Belt, Poland)

JAKUB BAZARNIK[1], PIOTR LENIK[1] and MAGDALENA PAŃCZYK[2]

1 – Polish Geological Institute – National Research Institute, Carpathian Branch, Skrzatów 1, 31-560 Kraków, Poland; e-mail: jakub.bazarnik@pgi.gov.pl

2 – Polish Geological Institute - National Research Institute, Micro-area Analysis Laboratory, Rakowiecka 4, 00-975 Warszawa, Poland

Neogene andesitic rocks represent the calc-alkaline magmatic event in the Polish part of the Pieniny Klippen Belt in Western Carpathians (Birkenmajer 2003; Birkenmajer & Pécskay 2000; Nejbert et al. 2012). They form broadly andesitic, small-volume hypabyssal dykes and sills that intrude both the Pieniny Klippen Belt and Magura nappe (the southernmost unit of Outer Carpathian flysch sediments). The Pieniny Klippen Belt forms a narrow, tectonic structure that separates the Outer and Inner Carpathians. It comprises deformed Mesozoic to Neogene sedimentary rocks.

The age of magmatism in the Polish part of Pieniny Klippen Belt is generally well known. The ages spread from 12.8 Ma to 10.8 Ma (Pécskay et al. 2015). However, most of the data were obtained using the K-Ar method (e.g., Pécskay et al. 2015). Previous U-Pb zircon dating was performed on numerous outcrops (Anczkiewicz & Anczkiewicz 2016), although it excluded Mount Wżar – the largest outcrop of andesitic rocks and some other important places for Neogene andesitic magmatism in the Polish part of the Western Carpathians (Małkowski 1958; Birkenmajer 1962; Yousseff 1978).

U-Pb dating of zircon was performed at the Micro-Analyses Laboratory at the Polish Geological Institute – NRI, Warszawa, using an ion microprobe SHRIMP IIe/MC. Prior to analysis, cathodoluminescence images were generated using a Hitachi SU3500 scanning electron microscope and used for placement of analytical spots.

The studied rocks represent a gray variety of andesites with large amphibole and pyroxene phenocrysts as well as a dark-brown andesite with feldspar phenocrysts. Preliminary results obtained from three samples from Mount Wżar and Szczawnica-Krościenko area show ages in the range of 11.44 – 10.24 Ma and 11.57 – 11.14 Ma, respectively. The results correlate well with the ages obtained by the K-Ar method by Pécskay et al. (2015).

Acknowledgement: The research is supported by the National Fund for Environmental Protection and Water Management project No. 22.2301.2001.00.1.

References:

Anczkiewicz, A.A. & Anczkiewicz, R. 2016. U–Pb zircon geochronology and anomalous Sr–Nd–Hf isotope systematics of late orogenic andesites: Pieniny Klippen Belt, Western Carpathians, South Poland. *Chemical Geology*, 427, 1–16.

Birkenmajer, K. & Pécskay, Z. 2000. K-Ar dating of the Miocene andesite intrusions, Pieniny Mts. West Carpathians, Poland: a supplement. *Studia Geologica Polonica*, 117, 7–25.

Birkenmajer, K. 1962. Forma geologiczna andezytów Wżaru, *Acta Geologica Polonica*, 12, 2, 201–211.

Birkenmajer, K. 2003. Post-collisional late Middle Miocene (Sarmatian) Pieniny Volcanic Arc, Western Carphatians. *Bulletin of the PAS: Earth Sci*., 51, 1, 79–89.

Małkowski, S. 1958. Przejawy wulkanizmu okolic Pienin. *Prace Muzeum Ziemii*, 1, 12–55.

Nejbert, K., Jurewicz, E. & Macdonald, R. 2012. Potassium-rich magmatism in the Western Outer Carpathians: Magmagenesis in the transitional zone between the European Plate and Carpathian–Pannonian region. *Lithos*, 146–147, 34–47.

Pécskay, Z., Gméling, K., Molnár, F. & Benkó, Z. 2015. Neogene calc-alkaline intrusive magmatism of post-collisional origin along the Outer Carpathians: a comparative study of the Pieniny Mountains and adjacent areas. *Annales Societatis Geologorum Poloniae*, 85, 1, 77–89.

Youssef, M.M. 1978. Large-scale geological survey of the Mt Wżar andesites, Pieniny Mts. *Studia Geologica Polonica*, 66, 1–30.

Morphotectonic evolution of the contact of the Malé Karpaty Mts. and Vienna Basin based on dating of cave levels in the Plavecký hradný vrch Hill

PAVEL BELLA[1,2], PAVEL BOSÁK[3], HELENA HERCMAN[4], ŠIMON KDÝR[3], PETR MIKYSEK[3], PETR PRUNER[3], JURAJ LITTVA[2], JOZEF MINÁR[5], MICHAL GRADZIŃSKI[6], WOJCIECH WRÓBLEWSKI[6] and MAREK VELŠMID[7]

1 – State Nature Conservation, Administration of Slovak Caves, Hodžova 11, 031 01 Liptovský Mikuláš, Slovak Republic; e-mail: pavel.bella@ku.sk

2 – Department of Geography, Catholic University in Ružomberok, Hrabovská cesta 1, 034 01 Ružomberok, Slovak Republic

3 – Institute of Geology, the Czech Academy of Sciences, Rozvojová 135, 165 00 Praha 6-Lysolaje, Czech Republic; e-mail: Bosak@gli.cas.cz

4 – Institute of Geological Sciences, Polish Academy of Sciences, ul. Twarda 51/55, 00 818 Warszawa, Poland

5 – Department of physical geography and geoinformatics, Faculty of Natural Sciences, Komenský Univerzity, Mlynská dolina, Ilkovičova 6, 842 15 Bratislava 4, Slovak Republic

6 – Institute of Geological Sciences, Jagiellonian University in Kraków, Gronostajowa 3a, 30-387 Kraków, Poland

7 – Jaskyniari Plavecké Predhorie, o. z., 906 36 Plavecké Podhradie 284, Slovak Republic

Plavecká jaskyňa (PJ) and Pec caves (PE) in the v Plavecký hradný vrch Hill (Malé Karpaty Mts., W Slovakia) are multi-phased hypogenic caves with several epiphreatic phases related to an intensified sulfuric acid dissolution (Bella et al. 2019, 2022). The low-temperature sulfuric acid development phases are indicated both by the presence of diagnostic minerals (gypsum and jarosite) and cave morphology. Hydrogen sulfide involved in the sulfuric acid speleogenesis was likely derived from anhydrites and/or hydrocarbon reservoirs with sulfate-saline connate waters in the fill of the Vienna Basin (VB). It ascended to the surface along deep-rooted sub-vertical fault zones at the contact of the VB with neighboring mountains (system of Leitha faults). Caves mostly contain horizontal passages and chambers with flat corrosion bedrock floors, fissure discharge feeders, wall water-table notches, replacement pockets, as well as a few other speleogens associated with sulfuric acid speleogenesis. Cave levels can be distinguished as follows: three in the PE from 295 to 283m asl, five in the PJ from 225 to 214 m asl. They record Early to Middle Pleistocene multi-phased relief evolution of the area. The minimum age of cave levels was determined by Th/U dating of speleothems and paleomagnetic analysis of rare cave sediments.

Cave levels developed in periods of distinctly decelerated and/or interrupted subsidence in adjacent part of the VB (Podmalokarpatská zníženina Depression/PD). Nevertheless, altitude levels separated by vertical steps only several meters high can be related also to Quaternary climatic changes. Three evolution levels in the PE developed probably at the end of Early Pleistocene and represent denudation relic of original much larger spaces. Flat corrosional bottom at 283 m asl is covered by normal(N)-polarized flowstone older than 600 ka and younger than 1.2 Ma belonging either to Bruhnes Chron or to Jaramillo Subchron. Two highest levels in the lower-lying PJ developed at the beginning of Middle Pleistocene. Fine-grained sediments at 225 m asl with jarosite are N-polarized. Flowstone on flat corrosional bottom at 223 m asl is older than 600 ka and younger than 1.2 Ma (Brunhes or Jaramillo). Upper levels in the PJ are tectonically uplifted to altitude of relics of the "river-side level" on the Lakšárská elevácia Elevation, east of the PD. Elevation is covered by Lower Pleistocene fluvial and Late Pleistocene eolian deposits. The difference in altitude of the "river-side levels" in the Malé Karpaty and on the Lakšárská elevácia probably resulted from differential vertical tectonic movements. It seems, that the tectonic movement is synchronous with the start of Late Quaternary neotectonic phase in the Western Carpathians (Vitovič et al. 2021). Sulfuric phase along the lowest cave level in the PJ at 214 m asl preceded the deposition of popcorn on the rim of flat corrosion bottom at subaerial (vadose) conditions dated to 270 ka.

The PD started to form by subsidence after the lowest level of the PJ developed, i.e. at the end of Middle Pleistocene, due to reactivation of tectonic activity in the VB round 250 to 300 ka ago (Salcher et al. 2012). This datum is agreement with the age of cave rafts deposited from meteoric water at 228 ka (Bella et al. 2022). The subsidence of the PD and its infill by sediments had continued during Late Pleistocene.

Acknowledgement: VEGA 1/0146/19 (SK) and RVO67985831 (CZ).

References:

Bella, P., Bosák, P., Mikysek, P., Littva, J., Hercman, H. & Pawlak, J. 2019. Multi-phased hypogene speleogenesis in a marginal horst structure of the Malé Karpaty Mountains, Slovakia. *International Journal of Speleology*, 48, 2, 203–220.

Bella, P., Hercman, H., Kdýr, Š., Mikysek, P., Pruner, P., Littva, J., Minár, J., Gradziński, M., Wróblewski, W., Velšmid, M. & Bosák, P. 2022. Sulfuric acid speleogenesis and surface landform evolution along the Vienna Basin Transfer Fault: Plavecký Karst, Slovakia. *International Journal of Speleology*, 51, 2, 105–122.

Salcher, B. C., Meurers, B., Smit, J., Decker, K., Hölzel, M. & Wagreich, M. 2012. Strike-slip tectonics and Quaternary basin formation along the Vienna Basin fault system inferred from Bouguer gravity derivatives. *Tectonics*, 31, 3, TC3004.

Vitovič, L., Minár, J. & Pánek, T. 2021. Morphotectonic configuration of the Podtatranská kotlina Basin and its relationship to the origin of the Western Carpathians. *Geomorphology*, 394, 107963.

Different structure of the crust in western, central and eastern Slovakia from magnetotelluric results

VLADIMÍR BEZÁK, JÁN VOZÁR, JOZEF MADZIN and LENKA ONDRÁŠOVÁ

*Geophysical Section, Earth Science Institute of the Slovak Academy of Sciences,
Dúbravská cesta 9, 840 05 Bratislava, Slovak Republic; e-mail: geofbezv@savba.sk*

The Western Carpathian orogenic belt has a very complicated structure. It incorporates the remains of tectonic fragments from all previous tectonic stages of tectonic development, mainly Hercynian, Paleoalpine and Neoalpine. Geophysics provides the best results for deciphering these often deep-seated tectonic fragments, especially when the results from several methods are integrated together.

We would like to present magnetotelluric (MT) models across the western, central and eastern parts of the Western Carpathians in order to show the differences in tectonic structure within a relatively small territory. The main method was magnetotellurics (MT) providing conductivity models of structures, which was combined with other geophysical methods. We selected three sections for comparison.

1/ Section MT-15, which crosses Slovakia in the west from the border with the Czech Republic to the border with Hungary in the NW-SE direction. The most striking on the MT model are the steep narrow conductive zones on the border of the current mountains and basins (horsts and grabenes), which correspond to the young fault structures. The movements on them were closely related to the origin of these geomorphological structures. This section shows the contact of the European platform with the Inner Western Carpathian block on the conductivity structure, which we identify as the Carpathian Conductivity Zone (CCZ). As well, there is a visible the offset in Moho depth, as two different crusts (Bohemian Massif and Inner Western Carpathians) meet here.

2/ Interpretation of MT measurements along the seismic profile 2T. From north to south, the 2T profile crosses all the basic tectonic units of the Outer and Inner Carpathians, and in addition to seismic, gravimetric and geothermal data were modelled on the section. Compared to the 2D model, the 3D MT model gives qualitatively new information about the physical properties of the crust along the profile and in its immediate vicinity. The new phenomena are highlighted in the 3D image, such as whole crustal conductivity zones at the boundary of physically contrasting blocks, namely the Carpathian conductivity zone (CCZ), the Pohorelá shear zone and some others fault zones. We see in 3D model a significant difference especially in the case of the interpreted CCZ, which was not visible in the 2D section. In the sections through 3D model the CCZ is clearly visible and we assume that it reflects significant shear zone.

3/ MT models in eastern Slovakia. In all preliminary models from this territory, we can see the dominant feature, which are middle-crust wide conductive zones. They are not in different profiles in the same position. Such structures have no equivalent in other profiles in central (2T) or western (MT-15) Slovakia, only with the exception of the southern part of the 2T profile, where it was interpreted as a young alternated crust by volcanic activity or hydrothermal fluids.

The conductive zones on profiles in the Eastern Slovakia we associate with Neoalpine tectonic processes in the Neogene. MT-04 profile runs from NW from Klippen Belt across the Inner Carpathian Paleogene basin then further through Gemericum complexes. MT model on this profile allows us to see overthrust of Klippen Belt complexes on Flysch Belt, its boundary with Inner Carpathian Paleogene complexes marked with relatively steep faults and also basement complexes depth.

Carpathian-Pannonian lithosphere: geophysical study

MIROSLAV BIELIK[1,2], DOMINIKA GODOVÁ[1,2],
HERMANN ZEYEN[3] and PAVLA HRUBCOVÁ[4]

1 – Earth Science Institute, Slovak Academy of Sciences, Dúbravská cesta 9, P. O. Box 106, 840 05 Bratislava, Slovak Republic; e-mail: geofmiro@savba.sk

2 – Department of Engineering Geology, Hydrology and Applied Geophysics, Faculty of Natural Sciences, Comenius University, Ilkovičova 6, 842 15 Bratislava 4, Slovak Republic

3 – Department des Sciences de la Terre Universite de Paris-Saclay, Bat. 504, F-91405 Orsay Cedex, France

4 – Department of Seismology, Institute of Geophysics of the Czech Academy of Sciences, Boční II/1401, 141 31 Prague 4, Czech Republic

The contribution deals with a review of our latest results obtained based on the integrated geophysical modelling of the lithosphere in the study area. This method was used due to uncertainty of single-method interpretation. Our study was applied along several transects that ran across the Carpathian-Pannonian territory. Most of them were transects, the course of which was identical to CELEBRATION 2000 profiles CEL01, CEL04, CEL05 and CEL09. Modelling of the lithospheric thermal structure was based on the joint interpretation of gravity, geoid, topography, and surface heat flow data with temperature-dependent density. The models for each profile were constrained by seismic modelling results. Based on these results a new map of the lithosphere-asthenosphere boundary is presented. The map is characterized by three main features. The first feature is a significant thickening of the lithosphere [(mantle lithospheric root (~240 km)] in the Eastern Carpathians, which we explain by a sinking of the upper part of the broken slab during the frontal continental collision. The second is no thickening of the mantle lithosphere (~100 km) in the junction zone of the Western Carpathians and the Bohemian Massif. This phenomenon is probably caused by the oblique continental collision. The third feature is represented by the elevation of the asthenosphere (~75 km) beneath the Pannonian Basin system, which was due to the extension of the lithosphere.

The esults indicate large variations of the lithosphere thickness from the old and cold East European Craton (~200 km) and the Trans European suture zone via the Western Carpathian orogeny to the young and hot Pannonian Basin (~90 km). Important differences in the lithospheric thickness were also found along-strike of the Western Carpathian orogeny and the Trans-European Suture Zone. The western part of the Western Carpathians is characterized by weak thickening of the lithosphere (only about 145 km), while their eastern segment presents strong lithospheric thickening (~190 km). The Małopolska unit in southern Poland has a lithospheric thickness of about 130 km. The thickest lithosphere (220 km) is observed around the junction of the Carpathian Foredeep and the East-European Craton.

For completeness, we also present a new crustal thickness map (Moho depth map), which was compiled based on all deep seismic measurements. In general, the course of the Moho discontinuity correlates well with the course of the lithosphere-asthenosphere boundary.

Updated Early Miocene Biochronology of Anatolia

MELIKE BILGIN[1,2], PETER JONIAK[3], SERDAR MAYDA[4], PABLO PELAEZ-CAMPOMANES[5], FIKRET GÖKTAŞ[6] and LARS VAN DEN HOEK OSTENDE[2]

1 – Natural History Museum in Belgrade, NegoŠeva 51, Belgrade 11000, Serbia; e-mail: melike.bilgin@naturalis.nl

2 – Naturalis Biodiversity Center, Leiden, The Netherlands

3 – Department of Geology and Palaeontology, Comenius University, Bratislava, Slovak Republic

4 – Faculty of Science, Biology Department, Ege University, Izmir, Turkey

5 – Museo Nacional de Ciencias Naturales, CSIC, Madrid, Spain

6 – MTA Geology Department, Ankara, Turkey

Fossil small mammals, especially rodents, are known as a very useful tool for dating terrestrial sediments, biogeographical studies and palaeoenvironmental reconstructions. Anatolia, the Asian part of Turkey, is rich in small mammal localities, including many fossils from the Early Miocene. During that time period, Anatolia formed, with the Balkans, a bio-province separated from western Europe, leading to correlation problems between the two areas. Therefore, creating a local zonation system was an important step to monitor faunal development in the region.

Ünay et al. (2003) constructed a preliminary zonation system of the Anatolian Neogene based on Muroidea, which are the best stratigraphic markers because of their rich and continuous records. This allowed them to provide accurate relative age estimates based on changes in the Anatolian rodent assemblages. For the correlation with the MN system, Ünay et al. (2003) took a straightforward approach, correlating the regional zones almost completely one on one to the MN units (Zone B = MN 1, Zone C = MN 2, etc.). However, MN units, as well as Anatolian local zones are biochronologic systems that are based on faunal content. As such, they can be diachronous in time, as has been shown for the MN system based on late Early and Middle Miocene sections (Van der Meulen et al. 2011).

Since 2003, a number of new localities have been discovered. A taxonomic description of the small mammal faunas of the new localities has enabled us to present an updated biostratigraphy and chronology of the Early Miocene of Anatolia. The new studies in the area focuses on the correlation with the time scale using old radiometric and magnetostratigraphic studies (Krijgsman et. al. 1996) combined with the new data from Gökler section, Belenyenice section and Beydere 3 locality (Lüdecke et. al. 2013; Bilgin et al. 2022). This implies that, if we follow the correlation to the MN units by Ünay et al. (2003), these units are clearly diachronic. This is in line with earlier studies, such as the assessment that the MN 4 locality of Aliveri should be dated between 17.5 and 18 Ma (e.g., Van den Hoek Ostende et al. 2015).

Acknowledgments: This work was supported by the Ege Üniversitesi (TTM/001/2016,TTM/002/ 2016); National Geographic Society (GEFNE 140-15); Spanish Ministry of Science and Innovation (MICU/AEI/FEDER,EU.PGC2018-094122-B-I00); Vedecká Grantová Agentúra MŠVVaŠ SR a SAV (1/0533/21).

References:

Bilgin, M., Joniak, P., Peláez-Campomanes. P., Göktaş. F., Mayda. S., Lorinser, C., Wijbrans, J., Kaya, T. & Van den Hoek Ostende, L. 2022. Beydere 3: a new early Miocene small mammal assemblage from the western Anatolia, Turkey. *Historical Biology*. doi:10.1080/08912963.2022.2077646.

Krijgsman, W., Duermeijer, CE., Langereis, CG., De Bruijn, H., Saraç, G. & Andriessen, PAM. 1996. Magnetic polarity stratigraphy of late Oligocene to middle Miocene mammal-bearing continental deposits in Central Anatolia (Turkey). *Newsletters on Stratigraphy*, 34, 13–29.

Lüdecke, T., Mikes, T., Rojay, B., Cosca, MA. & Mulch, A. 2013. Stable isotope-based reconstruction of Oligo-Miocene paleoenvironment and paleohydrology of Central Anatolian Lake basins (Turkey). *Turkish Journal of Earth Sciences*, 22, 1–28.

Ünay, E., De Bruijn, H. & Saraç, G. 2003. A preliminary zonation of the continental Neogene of Anatolia based on rodents. *Deinsea*, 10, 539–547.

Van den Hoek Ostende, LW., Mayda, S., Oliver, A., Madern, A., Hernández-Ballarín, V. & Peláez-Campomanes, P. 2015. Aliveri revisited, a biogeographical appraisal of the early Miocene mammals from the eastern Mediterranean. *Palaeobiodiversity and Palaeoenvironments*, 95, 3, 271–284.

Van der Meulen, AJ., Garcia-Paredes, I., Alvarez-Sierra, MA., Van den Hoek Ostende, LW., Hordijk, K., Oliver, A., Lopez-Guerrero, P., Hernández-Ballarín, V. & Peláez Campomanes, P. 2011. Biostratigraphy or biochronology? Lessons from the Early and Middle Miocene small Mammal Events in Europe. *Geobios*, 44, 2–3, 309–321.

A short note on the Middle Miocene (Badenian) brachiopods from the southwestern margin of the Central Paratethys, Croatia

MARIJA BOŠNJAK[1], KORALJKA BAKRAČ[2], JASENKA SREMAC[3], SANJA JAPUNDŽIĆ[1] and TOMISLAV MALVIĆ[4]

1 – Croatian Natural History Museum, Demetrova 1, Zagreb, Croatia; e-mail: marija.bosnjak@hpm.hr

2 – Croatian Geological Survey, Sachsova 2, Zagreb, Croatia

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

4 – University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering, Pierottijeva 6, Zagreb, Croatia

Fossil brachiopods are recorded in the Middle Miocene (Langhian/Serravalian – Badenian) deposits in Northern Croatia, Medvednica Mt. near Zagreb, which paleogeographically belonged to the southwestern margin of the Central Paratethys (e.g., Rögl 1998; Kováč et al. 2007; Piller et al. 2007; Sremac et al. 2022). The Badenian brachiopods from Northern Croatia are for the first time mentioned in Gorjanović-Kramberger (1908), and described by Kochansky (1944) and Kochansky-Devidé (1957). Since then, there have been no papers on the Badenian brachiopods from Croatia, except one unpublished Master Thesis by K. Bakrač (Sinković 1994). Specimens described in the above-mentioned papers are today housed in the Croatian Natural History Museum and we decided to conduct their revision.

A revision is based on the taxonomical review and biometry of the brachiopod specimens. In this paper we present preliminary results of this ongoing study. Brachiopods are represented by the class Rhynchonellata, with more than 700 specimens from the orders Rhynchonellida and Terebratulida, and the latter one prevails. Brachiopod assemblage from Northern Croatia shows similarity with the Miocene terebratulid record from Slovenia (e.g., Mikuž 2011 and references therein), and also comprises the species *Megerlia truncata* (Linnaeus, 1767), common in the Miocene deposits of the Central Paratethys (e.g., Bitner & Dulai 2004 and references therein). Several other brachiopod species, from the terebratulid family Megathyrididae, common in the Miocene of the Central Paratethys, e.g., *Argyrotheca cuneata* (Risso, 1826), *Megathiris detruncata* (Gmelin, 1790) and *Joania cordata* (Risso, 1826) (after e.g., Bitner & Dulai 2004 and references therein; Bitner et al. 2013 and references therein) are not recorded so far from the Miocene deposits of Northern Croatia. Study of the here presented brachiopod fauna could give further insight into the brachiopod biogeographical provinces and open marine connections in this area of the Central Paratethys during the Badenian Stage.

Acknowledgement: This research is part of the project "Mathematical researching in geology VII" (PI: Professor T. Malvić, University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering) and the Croatian Science Foundation Project IP-2019-04-7042 (Sedimentary paleobasins, water corridors and biota migration, PI: Professor M. Kovačić, University of Zagreb, Faculty of Science).

References:

Bitner, M.A. & Dulai, A. 2004. Revision of Miocene brachiopods of the Hungarian Natural History Museum, with special regard to the Meznerics collection. *Fragmenta Palaeontologica Hungarica*, 22, 69–82.

Bitner, M.A., Zágoršek, K. & Hladilová, Š. 2013. Deep-water brachiopod assemblage from the Middle Miocene of Kralice nad Oslavou, Moravia, southeastern Czech Republic. *Comptes Rendus Palevol*, 12, 81–89.

Gorjanović-Kramberger, D. 1908. Geologijska prijegledna karta k. Hrvatske i Slavonije. Tumač geologijskoj karti Zagreb (Zona 22, Col. XIV) [Geologische Übersichtskarte des königsreiches Kroatien-Slavonien. Erläuterungen zur geologischen Karte von Agram (Zone 22, Col. XIV)]. *Naklada Kr. zemaljske vlade, Odjela za unutarnje poslove, Zagreb.*

Kochansky, V. 1944. Fauna marinskog miocena južnog pobočja Medvednice (Zagrebačke gore) [Miozäne marine Fauna des südlichen Abhanges der Medvednica, Zagreber Gebirge]. *Vjestnik Hrv. drž. geol. zav. i Hrv. drž. geol. muz*. II/III, 171–280 (in Croatian with German summary).

Kochansky-Devidé, V. 1957. O fauni marinskog miocena i o tortonskom "šliru" Medvednice (Zagrebačke gore) [Ueber die Fauna des marinen Miozäns und über den tortonischen "Schlier" von Medvednica, Zagreber Gebirge]. *Geol. vjesnik* X (1956), 39–50 (in Croatian with German summary)

Kováč, M., Andreyeva-Grigorovich, A., Bajraktarević, Z., Brzobohatý, R., Filipescu, S., Fodor, L., Harzhauser, M., Oszczypko, N., Nagymarosy, A., Pavelić, D., Rögl, F., Saftić, B., Ľubomír, S. & Studencka, B. 2007. Badenian evolution of the Central Paratethys Sea: Paleogeography, climate and eustatic sea-level changes. *Geologica Carpathica*, 58, 579–606.

Mikuž, V. 2011. Brachiopods from Miocene beds near Šentilj in Slovenske Gorice, Northeast Slovenia. *Folia Biologica et Geologica*, 52, 3, 29–46.

Piller, W.E., Harzhauser, M. & Mandic, O. 2007. Miocene Central Paratethys stratigraphy—Current status and future directions. *Stratigraphy*, 4, 151–168.

Rögl, F. 1998. Palaeogeographic Considerations for Mediterranean and Paratethys Seaways (Oligocene to Miocene). *Ann. des Nat. Mus. Wien*, 99A, 279–310.

Sinković, K. 1994. Karpatski sedimenti i fosili na lokalitetu Plaz (jugoistočna Medvednica) [Karpatian sediments and fossils at the Plaz locality (southeastern part of the Medvednica Mt.)]. University of Zagreb, Faculty of Science and Faculty of Mining, Geology and Petroleum Engineering, Master Thesis, unpubl., 1–21.

Sremac, J., Bošnjak, M., Velić, J., Malvić, T. & Bakrač, K. 2022. Nearshore pelagic influence at the SW margin of the Paratethys sea – examples from the Miocene of Croatia. *Geosciences*, 12, 120.

3D resource modeling of selected mineral deposits in the Neogene Central Slovakia Volcanic Field, Western Carpathians

JANA BRČEKOVÁ[1], PETER UHLÍK[1], PETER KODĚRA[1], MAREK OSACKÝ[1], JAROSLAV LEXA [2] and MIROSLAV PERESZLÉNY[3]

1 – Department of mineralogy, petrology and economic geology, Faculty of Natural Sciences, Comenius University, Mlynská Dolina, Ilkovičova6, Bratislava, Slovak Republic; e-mail: jana.brcekova@uniba.sk

2 – Geological Institute, Earth Science Institute of the SAS, Dúbravská cesta 9, P.O.BOX 106, Bratislava, Slovak Republic

3 – PC&G, s.r.o., 842 15 Bratislava, Slovak Republic

The Central Slovakia Volcanic Field is situated on the inner side of the Carpathian arc that is a part of the northern branch of the Alpine orogenic belt of Europe and covers over 5000 km^2 in area (Konečný et al. 1995). This is the largest post-orogenic volcanic structure in the Western Carpathians.

The Neogene Central Slovakia Volcanic Field contains various mineral deposits. Major mining centres in the Neogene Central Slovakia Volcanic Field were one of the leading world producers of gold and silver in the 14th and 15th century (Bakos et al. 2004). The most important deposits are hosted by central zones of large stratovolcanoes. The best studied localities include Rozália mine intermediate sulphidation epithermal Au-Ag deposit in the Štiavnica stratovolcano, Kremnica low sulphidation epithermal Au-Ag deposit in the Kremnické Vrchy Mts., and Biely Vrch Au-porphyry deposit in the central zone of the Javorie stratovolcano (e.g., Koděra et al. 2014). The Central Slovakia Volcanic Field is also one of the largest areas in Europe featuring the occurrence of bentonite deposits. The most important deposits are situated in the southwestern part of the Kremnické vrchy Mts., (e.g., Baláž et al. 2015). The most well-known deposit is the Jelšový Potok I, where mining has continued since the 1960s until today. However, several new deposits have been opened in the last 10 – 15 years, while their mining is growing significantly (e.g., Osacký et al. 2019). From the point of view of reserves, the Lutila I deposite is one of the most important one.

During recent decades significant progress has been made in understanding of the mineralised paleohydrothermal systems in this region. 3D modelling is one of the main parts of the deposits innovative scientific research. Our contribution presents a summary of the current results of 3D modelling on Au-porphyry deposite - Biely Vrch and Lutila bentonite deposits.

The goal of 3D modelling was to create conceptual models that include spatial visualization of geology, mineralogical and geochemical parameters of the deposits. The models include a surface geological map of deposits areas. Modelling on both deposits was done on the basis of a database provided by exploration companies in various formats (Biely Vrch deposite – Emed Mining Ltd. – 52 boreholes, 14,482 drill core samples; Lutila I. deposite – REGOS, s.r.o, XLS tables, approx. 1,400 drill core samples). Data from the database, geological sections and results of surface geological mapping were used to create a visualization of the geological boundaries and tectonic structures of the deposits. The 3D distribution of geochemical and mineralogical data was made from chemical element analyses provided by exploration firms (ICP, AAS, MM) and obtained during scientific research (XRD, microscopy). Spatial geochemical/mineralogical distribution was applied to specific geological domains.

Vector layers were done using QGIS software, 2D section of both deposits and 3D geochemical distributions of alteration zones at Biely Vrch deposit were done using MapInfo Discover 3D software, which offers explicit methods of 3D modelling and geochemical modelling using the Kriging interpolation method. Alteration boundaries were modelled using Voxel Calculator tool of Discover 3D software. Threshold values of input models were determined according to results of geochemical modelling of alteration patterns. Correlation analysis between ore grades, geochemical associations, chemical ratios and quantitative analysis of minerals was done for determining of threshold values of alteration boundaries.

3D geology models of both deposits and the visualisation of all parameters of the Lutila I deposit were done using Leapfrog Geo software. From sectional interpretations and outlining of top and bottom of montmorillonite mineralization were created 3D deposit boundaries at 40 % montmorilonite cut off. In this domain, the distribution of montmorillonite was modelled in % determined on the basis of the methylene blue method. Distribution model was developed by RBF interpolation method. This method was used also for making of kaolin, perlite, tuff and rhyolite boundaries.

Acknowledgement: The work is supported by the grant APVV-20-0175, VEGA 1/0313/20.

References:

Bakos, F., Chovan, M., Bačo, P., Bahna, B., Ferenc, Š., Hvožďara, P. Jeleň, S., Kamhalová, M., Kaňa, R., Knésl, J., Krasnec, Ľ, Križáni, I., Maťo, Ľ., Mikuš, T., Pauditš, P., Sombathy, L. & Šály, J. 2004. *Gold in Slovakia*. Slovenský skauting, Bratislava. 298 pp. (in Slovak with English summary).

Koděra, P., Lexa, J., Fallick, A.E., Wälle, M. & Biroň, A. 2014. Hydrothermal fluids in epithermal and porphyry Au deposits in the Central Slovakia Volcanic Field. *In: Garofalo, P. S. & Ridley, J. R. (eds) Gold-Transporting Hydrothermal Fluids in the Earth's Crust. Geological Society, London, Special Publications*, 402, 177–206.

Konečný V., Lexa J., Balogh, K. & Konečný P. 1995. Alkali basalt volcanism in Southern Slovakia - Volcanic forms and time evolution. *Acta Vulcanologica*, 7, 2, 167–171.

Baláž P. & Kušík D. 2015. *Slovak Minerals Yearbook 2015*. ŠGÚDŠ, Bratislava. 145 pp.

Osacký, M., Binčík, T., Paľo, T., Uhlík, P., Madejová, J. & Czímerová, A. 2019. Mineralogical and physico–chemical properties of bentonites from the Jastrabá Formation (Kremnické vrchy Mts., Western Carpathians) *Geologica Carpathica*, 70, 5, 433–445.

Two geochemical types of West-Carpathian Permian felsic magmatism and their geotectonic implications

IGOR BROSKA[1], MICHAL KUBIŠ[1], MARTIN ONDREJKA[2] and MAREK VĎAČNÝ[1]

1 – Earth Science Institute of the Slovak Academy of Sciences, Dúbravská cesta 9, 840 05 Bratislava, Slovak Republic; e-mail: igor.broska@savba.sk

2 – Department of Mineralogy, Petrology and Economic Geology, Comenius University in Bratislava, Ilkovičova 6, 842 15 Bratislava, Slovak Republic

The Permian felsic granite magmatism is widely spread over the Central Europe. After the Variscan orogeny, the present Eastern Alps experienced Permian-Triassic extension associated with continental rifting and occurrence of the large A-type granite magmatism. The rift-related granites show the A-type affinity across the Eastern Alps, Western Carpathians and Tisza Mega-unit. Recently, Triassic granites recognised from the Eastern Alps geochemically show features of arc-related magmatism. Huang et al. (2022) concluded that the Permian to Triassic magmatism in the Eastern Alps and in comparison also in the Western Carpathians formed in response to the subduction of Paleotethys Ocean resulting in the opening of the Meliata back-arc oceanic basin. The locations of Permian magmatism from Tisza Mega-unit recently reported Máté Szemerédy. The continuation of Permian magmatism to Sakar/Strandja and Istanbul zones recently was described by Salacińska et al. (2022) and this Permian magmatism is considered as Paleotethys subduction-related phenomenon (Bonev et al. 2019).

The Permian felsic magmatism in the Western Carpathians forms two distinct geochemical groups: (1) A-type granites and (2) specialised S-type Gemeric granites. In spite of their similar ages and common high SiO_2 and K_2O content or similar pronounced negative Eu anomaly, there are many principal differences indicating their origin from different protolith in probably different geotectonic circumstances. High iron biotite and increased amount of HFSE minerals are typical for the A-type granites and local hypersolvus alkali feldspars indicate their origin from hot melts. On the other hand, the specialised S-type Gemeric granites are enriched in volatiles and, in comparison to A-type, they are rich also in phosphorus, uranium and boron. Due to volatiles, their cupolas form rare-metal granites with special rare Nb-Ta, W, Sn mineralisation. They are derived from a barren porphyritic biotite granite body with S-type characteristics, although some locations show A-type features indicated by local high Zr content. Emplacements of the volatile-rich leucocratic apexes were followed by intrusions of bottom porphyritic biotite granite and hereby they formed composite magmatic bodies. Their geochemistry indicates a clay-rich melted source which is not the case of the A-type granites.

From bulk-rock chemistry and isotopic data, the A-type granites are related to melting of felsic lower crustal material, probably along rifts within Pangaea (Ondrejka et al. 2021). The origin of the Gemeric granites was linked by Vilaseñor et al. (2021) to a post-collisional extension in the initial Alpine rifting stage. But other data indicate that the specialised S-type Gemeric granites are attributed to melting in thickened crustal roots formed in orogenic wedge during subduction of Paleotethys beneath Paleo-Adria whose position paleogeographically defined Neubauer et al. (2022). The forming of crustal root (similarly like in recent Ands) must be due to isostatic balance responsible for high elevation along the active Paleo-Adria continental margin. This elevation associated with thickened crust became a source for melting of recycled material in the continental crust, e.g. for Gemeric granites. Recent models for genesis of the A-type and S-type Gemeric granites take into account a link of their formation to forming of back-arc Triassic Meliata Basin. Besides the definition of the two types of the Permian West-Carpathian magmatism, our contribution presents also the possible role of the Permian Hronic extensional basin which could be involved to initialization of the felsic magmatism. The Hronic trough which started from the Upper Carboniferous contains the thick sedimentary strata with several andesite-basalt volcanic horizons giving enough heat for melting of the crust for felsic granites. The formation of the A-type granites could result from heat transfer to lower crust by Hronic mafic magmatism which timely was older than the Meliata rifting system. The origin of Hronic trough could indicate the beginning of Paleotethys subduction which had to be connected with origin of intrusive magmatism and probably also the Gemeric granites.

Acknowledgements: The research was financed by the project VEGA 1/0168/22.

References:

Bonev, N., Filipov, P., Raicheva, R. & Moritz, R. 2019. Timing and tectonic significance of Paleozoic magmatism in the Sakar unit of the Sakar-Strandzha Zone, SE Bulgaria. *International Geology Review*, 61, 16, 1959–1979.

Neubauer, F., Liu, Y., Dong, Y., Chang, R., Genser, J. & Yuan, S. 2022. Pre-Alpine tectonic evolution of the Eastern Alps: From Prototethys to Paleotethys. *Earth Science reviews*, 226. doi.org/10.1016/j.earscirev.2022.103923

Huang, Q., Neubauer, F., Liu, Y., Genser, J., Guan, Q., Chang, R., Yuan, S. & Yu, S. 2022. Permian-Triassic granites of the Schladming complex (Austroalpine basement): Imlications for subduction of the Paleo-Tethys Ocean in the eastern Alps. *Gondwana Research*, 109, 205–224.

Sałacińska, A., Gerdjikov, I., Kounov, A., Chew, D., Szopa, K., Gumsley, A., Kocjan, I., Marciniak-Maliszewska, B. & Drakou, F. 2022. Variscan magmatic evolution of the Strandja Zone (Southeast Bulgaria and northwest Turkey) and its relationship to other north Gondwanan margin terranes. *Gondwana Research*, 109, 253-273.

Ondrejka, M., Uher, P., Kohút M., Broska, I., Larionov, A., Bojar, A.V. & Sobocký, T. 2021. Permian A-type granites of the Western Carpathians and Transdanubian regions: product of the Pangea supercontinent breakup. *International Journal of Earth Sciences*, 110, 2133–2155.

Vilaseñor, G., Catlos, E.J., Broska, I., Kohút, M., Hraško, Ľ., Aguilera, K., Etzel, T.M., Kyle, J.R. & Stockli D.F. 2021. Evidence for widespread mid-Permian magmatic activity related to rifting following the Variscan orogeny (Western Carpathians). *Lithos*, 390–391, 106083.

Paleoenvironmental characteristics of the Badenian locality Borský Mikuláš-Vinohrádky (Vienna Basin, Slovakia) based on study of fish otoliths and foraminifera

ROSTISLAV BRZOBOHATÝ[1], BARBARA ZAHRADNÍKOVÁ[2]
and NATÁLIA HUDÁČKOVÁ[3]

1 – Department of Geology, Masaryk University, Kotlářská 2, 61137 Brno, Czech Republic; e-mail: rosta@sci.muni.cz

2 – Slovak National Museum - Natural History Museum in Bratislava, Vajanského nábr. 2, P.O.BOX 13, 810 06 Bratislava, Slovak Republic; e-mail: barbara.zahradnikova@snm.sk

3 – Department of Geology and Paleontology, Comenius University, Mlynská dolina, Ilkovičova 6, 842 15 Bratislava, Slovak Republic

The locality of Borský Mikuláš-Vinohrádky is a small outcrop located in the area of the lowland Záhorská nížina (Vienna Basin), southwest of the town of Senica (Western Slovakia). It is situated at a spring within vineyards, about 200 m from Kote 257 Vinohrádky, on the right side of the road from Borský Mikuláš to Lakšárska Nová Ves (Fordinál et al. 2014). The upper Badenian stratum forms the highest elevations of the Miocene since it is located on the tectonic unit known as the Lakšár Elevation. The Badenian sediments appear in an outcrop at a height of 2 – 3 metres. Sand and clay alternate with sporadic layers of small to coarse-grained gravel (Baráth et al. 1994).

We provide here the results of processing a rich collection of fossil material of otoliths available for study (~6,000 specimens) collected by Tomáš Mlynský, the curator of the Balneological Museum Imricha Wintera in Piešťany, Slovakia. The otoliths are deposited in the collections of the SNM-Natural History Museum in Bratislava, Slovakia (Inv. Nr. Z 28227 - Z 28281).

In the Borský Mikuláš-Vinohrádky section were identified 38 otolith-based taxa of Teleostei - *Panturichthys subglaber* (Schubert 1906); *Encheliophis* sp.; *Gobius* aff. *niger* Linnaeus 1758; *G. supraspectabilis* Schw., Brz., Radw. & Proch. 2020; *Lesueurigobius magniiugis* Schwarzhans 2017; *L. suerii* (Risso 1810); *L. vicinalis* (Koken 1891); *Thorogobius iucundus* Schwarzhans 2014; *Liza* sp.; *Lepidorhombus* sp.; *Pomadasys* aff. *incisus* (Bowdich 1825); *Dicentrarchus* sp.; *Chelidonichthys* sp.; *Platycephalus* sp.; '*Polynemis*' *huyghebaertae* Steurbaut & Jonet 1982; *Argyrosomus* aff. *regius* (Asso 1801); *Dentex* aff. *maroccanus* Valenciennes 1830; *D.* aff. *gibbosus* (Rafinesque 1810); *Diplodus karrerae* Nolf & Steurbaut 1979; *Diplodus* sp.; ?*Diplodus* sp. and two new species *Gerres mlynskyi* Brz., Zahr. & Hudač. 2022 and *Thorogobius antirostratus* Brz., Zahr. & Hudač. 2022.

From the foraminifera the 41 species were identified - *Ammonia inflata* (Seguenza 1862); *A. tepida* (Cushman 1926); *A. viennensis* (d'Orbigny 1846); *Amphistegina lessonii* d'Orbigny in Guérin-Méneville 1832; *Asterigerinata mamilla* (Williamson 1858); *Biasterigerina planorbis* (d'Orbigny 1846); *Borelis melo* (Fichtel & Moll 1798); *Cancris auricula* (Fichtel & Moll 1798); *Cibicides crassiseptatus* Łuczkowska 1960; *Cibicidoides* ex gr. *ungerianus* (d'Orbigny 1846); *C. lobatulus* (Walker & Jacob 1798); *C. pachyderma* (Rzehak 1886); *Cymbaloporetta* sp.; *Discorbis* sp.; *Elphidium advenum* (Cushman 1922); *E. crispum* (Linnaeus 1758); *E.*

fichtelianum (d'Orbigny 1846); *E. flexuosum* var. *reussi* Marks 1951; *E. josephinum* (d'Orbigny 1846); *E. macellum* (Fichtel & Moll 1798); *Elphidium* sp.; *Fursenkoina subacuta* (d'Orbigny 1852); *Globigerina bulloides* d'Orbigny 1826; *Globulina punctata* d'Orbigny 1846; *Guttulina austriaca* d'Orbigny 1846; *Haynesina depressula* (Walker & Jacob 1798); *Miniacina miniacea* (Pallas 1766); *Neoeponides* sp.; *Nonion* cf. *tumidulus* Pishvanova 1960; *Porosononion granosum* (d'Orbigny 1846); *Pseudotriloculina consobrina* (d'Orbigny 1846); *Quinqueloculina striolata* Reuss 1850; *Quinqueloculina* sp.; *Reussella spinulosa* (Reuss 1850); *Reussella* sp.; *Rosalina globularis* d'Orbigny 1826; *Rotalia* sp.; *Saccammina* sp.; *Sahulia conica* (d'Orbigny 1839) and *Triloculina* sp.

The otoliths and foraminifera document a normal marine environment of well-aerated shallow water of 30 – 50 metres depth, with muddy to sandy bottom. Foraminifera documents marine meadows and plenty of light in the subtropical climatic conditions. Several fish genera (for example *Gerres*) give evidence for the nearness of reef structures. There are no species (excepting *Lesueurigobius vicinalis*) in common with the known Lower Serravallian otolith fauna from the Eastern Paratethys. Overall, the family of Gobiidae dominate in the assemblage of otoliths (>90 % of specimens). Meso- and epipelagial fishes or diversified gadids and sciaenids are missing. Among foraminifera epiphytic taxa such as *Biasterigerina planorbis* and *Elphidium crispum* associated with other elphidiids, *Lobatula lobatula* and *Cibicides crassiseptatum* prevail.

Acknowledgement: It is a pleasure for us to thank Tomáš Mlynský (the curator of I. Winter Balneological Museum Piešťany, Slovakia) for providing the otoliths from the Borský Mikuláš-Vinohrádky locality.

References:

Baráth, I., Nagy, A. & Kováč, M. 1994. Sandberské vrstvy - vrchnobádenské marginálne sedimenty východného okraja Viedenskej panvy. *Geologické práce*, *Správy*, 99, 59–66.

Fordinál, K., Kráľ, J., Harčová, E., Čech, P., Zieliński, G. & Nagy, A. 2014. $^{87}Sr/^{86}Sr$, $\delta^{13}C$ a $\delta^{18}O$ vo fosílnych schránkach mäkkýšov z morského, brakického a sladkovodného prostredia terciéru Západných Karpát. *Mineralia Slovaca*, 46, 23–44.

First fossil representative of Sediment Hosted Vent ecosystems from Zengővárkony (Mecsek Mountains, Tisza Mega-unit, South Hungary, Early Cretaceous)

LÁSZLÓ BUJTOR

Institute of Geography and Environmental Sciences, Eszterházy Károly Catholic University, 6-8 Leányka Street, H-3300 Eger, Hungary; e-mail: bujtor.laszlo.geology@gmail.com

In many cases the outstanding faunal richness or unusual size distribution in fossil communities may refer to unique or particular ecological-environmental conditions. The lower Cretaceous sedimentary iron-ore body at Zengővárkony (Mecsek Mountains, South Hungary, Tisza Mega-unit) provided the most diverse crustacean microcoprolite ichnofauna of the Mesozoic (Palik 1965) and 6 species are described as new species. Size distribution of brachiopods from the iron-ore deposit revealed 26 – 71 % size increase compared to their type locality populations (Bujtor & Vörös 2019). Besides brachiopods, echinoderm spines also revealed average size increases of 41 – 54 % (Bujtor and Nagy 2021).

The origin of this tiny sedimentary ore body was a mystery for Hungarian geology for decades. Bujtor (2007) proposed a genetic model for the environment and linked this succession to the continental rifting and early Cretaceous volcanism of Tisza Mega-unit, however in the lack of recent analogous environment this was not fully convincing. This environment did not show the typical C and O stable isotope ratios decisive for vent or seep biotas because:

Intra-plate hydrothermal vents are rare, accounting for only 1 % of active recent vent sites (Beaulieu and Szafrański 2013).

These environments are even more unique when they are generated in shallow marine settings where there are no high temperature vents with strong fluid transport, but there are low temperature, sediment-hosted vents (Bell et al. 2016).

Bacterial activities around hydrothermal venting is known either it is hot (Jannasch and Wirsen 1981) or tepid (Sievert et al. 1999) and bacterial activity results sulfur-isotope fractionating that is independent from the taxonomic position of the related bacteria being a general tool to recognize bacterial sulphate-reduction activities in the fossil record. Stable S isotope measures of the Zengővárkony locality revealed highly negative values (from -19.27 to -40.39 δ^{34}S % CDT).

Both direct and indirect evidence contribute to understanding the kind of ecosystem exemplified by the Zengővárkony SHV:

1) *Submarine volcanic* (pillow lavas, peperites, hydrothermal sediments, vesicularity index).

2) *Sulphur stable isotope data* (unusually negative values, which can indicate bacterial life).

3) *High diversity fauna* (displaying an unusual average size increase).

4) *Diverse crustacean microcoprolite ichnofauna* (can occur in rock-forming quantities).

5) *Rich taxonomic composition* of major faunal groups showing high specimen abundance.

6) *Endemism among multiple fossil groups*.

This environment belongs to the group of rare, shelfal, hydrothermally influenced palaeoenvironments formed on continental crust. Water depth was most probably between 100 and 150 m. Recent observations (Ferretti et al. 2019) from a similar modern volcanic built-up, and its effects on the marine environment located on continental crust around the Aeolian Islands (Tyrrhenian Sea) support the recognition of this fossil SHV environment and helps to understand better its bathymetry, ecological conditions and ore-formation.

References:

Beaulieu, S.E. & Szafrański, K.M. 2020. InterRidge Global Database of Active Submarine Hydrothermal Vent Fields Version 3.4. *PANGAEA*.

Bell, J.B., Woulds, C., Brown, L.E., Sweeting, C.J., Reid, W.D.K., Little, C.T.S. & Glover, A.G. 2016. Macrofaunal ecology of sedimented hydrothermal vents in the Bransfield Strait, Antarctica. *Frontiers in Marine Science*, 3, 32, 1–16.

Bujtor, L. 2007. A unique Valanginian paleoenvironment at an iron-ore deposit near Zengővárkony (Mecsek Mts., South Hungary) and a possible genetic model. *Central European Geology*, 50, 183–198.

Bujtor, L. & Nagy, J. 2021. Fauna, palaeoecology and ecotypes of the Early Cretaceous sediment hosted hydrothermal vent environment of Zengővárkony (Mecsek Mountains, Hungary). *Palaeogeography, Palaeoclimatology, Palaeoecology*, 564, 110179.

Bujtor, L. & Vörös, A. 2019. New kingenoid (Terebratellidina) brachiopods with larger body sizes from the Early Cretaceous of Zengővárkony (Mecsek Mountains, Hungary). *Journal of Paleontology*, 94, 3, 475–488.

Ferretti, A., Messori, F., Di Bella, M., Sabatino, G., Quartieri, S., Cavalazzi, B., Italiano, F. & Barbieri, R. 2019. Armoured sponge spicules from Panarea Island (Italy): implications for their fossil preservation. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 536, 109379.

Jannasch, H.W. & Wirsen, C.O. 1981. Morphological Survey of microbial mats near Deep-Sea Thermal Vents. *Applied and Environmental Microbiology*, 41, 2, 528–538.

Palik, P. 1965. Remains of crustacean excrement from the Lower Cretaceous of Hungary. *Micropaleontology*, 11, 1, 98–104.

Sievert, S.M., Brinkhoff, T., Muyzer, G., Ziebis, W. & Kuever, J. 1999. Spatial heterogeneity of bacterial populations along an environmental gradient at a shallow submarine hydrothermal vent near Milos Island (Greece). *Applied and Environmental Microbiology*, 65, 9, 3834–3842.

Distributional patterns of the Miocene Talpidae (Eulipotyphla) from the Western Carpathians

FLORENTIN CAILLEUX[1, 2], LARS W. VAN DEN HOEK OSTENDE[2] and PETER JONIAK[1]

1 – Comenius University, Department of Geology and Palaeontology, SK-842 15 Bratislava, Slovak Republic; e-mail: cailleux1@uniba.sk

2 – Naturalis Biodiversity Center, Darwinweg 2, 2333 CR Leiden, The Netherlands

The Talpidae display a wide range of locomotor habits, from terrestrial ambulatory to swimming, and various degrees of fossoriality. Observation of the fossorial and semiaquatic *Condylura* even revealed climbing abilities (e.g., Norris and Kilpatrick 2007). These adaptations allowed the Talpidae to fill ecological niches and create new, specialized ones. Additionally, the spread of these species into new regions surely led to interspecific competition. While modern-day moles exhibit poor regional diversity and disparity, this is far from mirroring the situation observed during the Miocene where the co-occurrence of several species was the norm. The Miocene of Central Europe constitutes a well-known case of study since it contains sites with exceptionally high diversity of Talpidae, such as in the Austrian locality of Schernham (Ziegler 2006). A similar observation is expected with the Western Carpathians fauna, of which rich material has become available through recent fieldworks. Here are reported preliminary results based on these findings.

Early and Middle Miocene Slovak data are unfortunately extremely scarce (Sabol et al. 2021) and restricted to the new locality Baňa Dolina (MN4) and the famous karstic fissures from Devínska Nová Ves (MN6; Fejfar and Sabol 2005). The few faunal evidences rather support that the Talpidae from the Western Carpathians displayed adaptations similar to the one from Central Austria and Southern Germany, including terrestrial, semiaquatic and different types of fossorial taxa. There is little evidence for major changes in the ecosystem between the Middle Miocene and the early Late Miocene faunas, suggesting stable environmental conditions for Talpidae.

Eleven species are firmly recognized from the Late Miocene of Slovakia, which is equal to the number of recognized species in Austria (Ziegler 2006). The last European occurrence of *Desmanodon* is attested in the MN9 of Borský Svätý Jur, proving its survival into the Late Miocene of Europe. The Western Carpathians may be seen as a refuge for the last European populations. The terrestrial uropsiline *Desmanella* is frequent in both Vallesian and Turolian localities. The semiaquatic Desmaninae are well-represented throughout the Late Miocene with four species. The two species identified in the MN12 locality of Šalgovce 5 are not found elsewhere. A stock of the fossorial scalopine *Proscapanus* seems present in the Carpathian area, as shown by *P. austriacus* and *P. metastylidus*. The numerous specimens identified from the Vallesian Slovak material of the Vienna basin support the sympatric emergence of *P. austriacus* from the smaller *P. minor* during the late MN9. Apart from the cases mentioned above, the material from the Late Miocene of Slovakia is distinct from the one of Austria by the lack of large-sized talpids, namely *Urotrichus giganteus*, *Talpa vallesiensis* and *Talpa* aff./cf. *gilothi*.

The only Talpini identified from Slovakia is the extremely rare *Talpa* cf. *minuta*, while this tribe is much more represented in Austrian fauna compared to Scalopini. Interestingly, this assessment is based mostly on the material extracted from the Austrian and Slovak parts of the Vienna basin, indicating that the distribution of these two fully-fossorial tribes were hardly overlapping during the Vallesian. Considering the similar ecological signal of these taxa (see Klietmann 2013), such observation is coherent with the competitive exclusion principle. With the sympatric evolution of *Proscapanus*, this supports that the high regional diversity of Talpidae in the Western Carpathians was mostly related to trophic and ecological factors rather than geographic barriers and intermountain endemism.

Concentrated regional diversity of Talpidae mostly occurs nowadays because of geographic vicariance and not co-occurrence. Our data suggest that the competitive exclusion principle already had consequences on talpid paleodiversity, but this competition was tempered in the Late Miocene of the Western Carpathians by their higher ecological adaptations and phylogenetic disparity. The heterogeneous and rich-resources areas from Central Europe, favored by the evolution of the Pannonian basins system, provided a wide range of trophic specialization and ecological niche for dissimilar groups as long as climatic parameters remained stable. Miocene Talpidae constitutes thus a powerful indicator of local resources and ecological richness.

Acknowledgement: This research was supported by grant UK/27/2022 of Comenius University and the Scientific Grant Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic (VEGA 1/0533/21).

References:

Fejfar, O. & Sabol, M. 2005. The Fossil Record of the Eurasian Neogene Insectivores (Erinaceomorpha, Soricomorpha, Mammalia), Part I.: Czech Republic and Slovak Republic. *Scripta Geologica*, Special Issue 5, 51–60.

Klietmann, J. 2013. Systematic and ecological analysis of Marsupialia and Eulipotyphla from Petersbuch 28 (Germany, lower Miocene) [Ph.D. Thesis]. Vienna, Austria, University of Vienna. 484 pp.

Norris, R.W. & Kilpatrick, C.W. 2007. A High Elevation Record of the Star-nosed Mole (*Condylura cristata*) in Northeastern Vermont. *The Canadian field-naturalist*, 121, 206–207.

Sabol, M., Joniak., P., Bilgin, M., Bonilla-Salomón, I., Cailleux, F., Čerňanský, A., Malíková, V., Šedivá, M. & Tóth, C. 2021. Updated Miocene Mammal Biochronology Of Slovakia. *Geologica Carpathica*, 72, 425–443.

Ziegler, R. 2006. Miocene Insectivores from Austria and Germany–an overview. *Beiträge zur Paläontologie*, 30, 481–494.

Mélanges of the Pieniny Klippen Belt in the shallow Seismic Refraction Tomography Image

KAMIL CICHOSTĘPSKI and JERZY DEC

AGH University of Science and Technology, Faculty of Geology, Geophysics and Environmental Protection, al. Mickiewicza 30, 30-059 Kraków, Poland; e-mail: geodec@agh.edu.pl

The Pieniny Klippen Belt (PKB) is located in the suture zone between the Central and Outer (Flysch) Carpathians. The geographic part of this name indicates the mountain range in Poland and Slovakia where numerous cliffs (klippen in German) were recognized (Golonka et al. 2015, 2018). The “Klippen” are relatively erosion-resistant blocks surrounded by the less competent rocks. These blocks were traditionally considered as exotic tectonic slivers, however recently, the occurrence of olistoliths in klippen belts was strongly emphasized and the possible contribution of sedimentary-gravitational processes in formation of the PKB was postulated (e.g., Cieszkowski et al. 2009; Jurewicz 2018). In this zone, tectonic components of different ages and features, including strike-slip-bounded tectonic blocks, thrust units, as well as toe-thrusts and olistostromes, result in the present-day mélange characteristics of the PKB, where individual tectonic units are difficult to distinguish. Several different views concerning the PKB mélange culminated in the most recently published discussions, and diverging opinions exist between geologists working in particular sectors of the PKB. The problematic structure of the PKB is still controversial and full of intricacies.

To aid the geological interpretation of the mélanges of PKB, the authors conducted geophysical measurements – seismic refraction tomography. Geophysical methods allow for non-invasive identification and attempt to distinguish between individual geological units located in the subsurface, and to trace their underground occurrence. The geophysical methods are measurements of physical quantities (impedance, speed of seismic wave propagation, density, electrical resistivity, conductivity, etc.) aimed at identifying comprehensively the rock mass structure and lithological characteristics of the subsurface.

To obtain the subsurface image, the seismic refraction tomography (SRT) measurements were carried out along three profiles within the PKB. The study area was located in the Spiskie Pieniny Mts. region, in the area of several limestone blocks occurrences, with the most popular being Obłazowa-Kramnica and Lorencowe Skałki, occurring in mild morphology. The seismic profiles were normally oriented through a “belt of limestone outcrops”, but there were no limestone outcrops in the profiles themselves. Each of the SRT profiles was 1,075 m long, and maximum depth of seismic imaging was 90 m. It covered the PKB structure and surrounding contiguity. This method utilizes artificially generated seismic waves that propagate through subsurface media at different speeds depending on the lithology, weathering, fractures, porosity and pore infill, density and other physical properties. This allows interpretation of the subsurface geology.

Authors would like to present the results of the recently conducted seismic refraction tomography (SRT) survey that made it possible to carry out a near surface investigation of the PKB.

Acknowledgement: This research was financially supported by the Polish National Science Center grant NCN no. 2019/35/B/ST10/00241 and by the AGH University of Science and Technology subsidy funds no. 16.16.140.315.

References:

Golonka, J., Krobicki, M., Waśkowska A., Cieszkowski, M. & Ślączka, A., 2015. Olistostromes of the Pieniny Klippen Belt, Northern Carpathians. *Geological Magazine*, 152, 269–286.

Golonka, J., Pietsch, K. & Marzec, P. 2018. The North European Platform suture zone in Poland. *Geology, Geophysics & Environment*, 44, 5–16.

Cieszkowski, M., Golonka, J., Krobicki, M., Ślączka, A., Oszczypko, N., Waśkowska, A. & Wendorff, M. 2009. The Northern Carpathians plate tectonic evolutionary stages and origin of olistoliths and olistostromes. *Geodynamica Acta*, 22, 1–26.

Jurewicz, E. 2018. The Šariš Transitional Zone, revealing interactions between Pieniny Klippen Belt, Outer Carpathians and European platform. *Swiss Journal of Geosciences*, 111, 245–267.

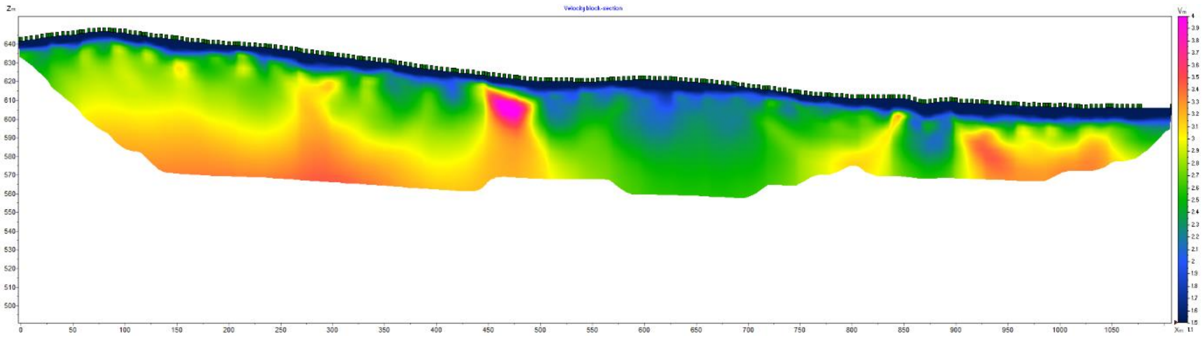


Figure 1: The result of seismic refraction tomography along one of three profiles conducted in the Spiskie Pieniny Mts. region.

The multidisciplinary approach of studying the Middle Eocene warming episodes in Dinaric foreland basin: new data or unfulfilled promises?

VLASTA ĆOSOVIĆ[1], ĐURĐICA PEZELJ[1], IGOR PEJNOVIĆ[1], MARINA ČANČAR[1], DAMIR BUCKOVIĆ[1], DRAŽEN KURTANJEK[1], NENAD TOMAŠIĆ[1], ŽELJKO IŠTUK[1], DUNJA ALJINOVIĆ[2], INES GALOVIĆ[3], MARIJA HORVAT[3] and STJEPAN ĆORIĆ[4]

1 – Department of Geology, Faculty of Science, University of Zagreb, Horvatovac 102b,1000 Zagreb, Croatia; e-mail: vcosovic@geol.pmf.hr

2 – Department of Mineralogy, Petrology and Mineral Resources, Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Pierottijeva 6, 10000 Zagreb, Croatia

3 – Croatian Geological Survey, Sachsova 2, 10000 Zagreb, Croatia

4 – Geological Survey of Austria, Neulinggasse 38, 1030 Vienna, Austria

In the central Neo-Tethys (Dinaric foreland basin, Croatia) the middle Eocene sediments are arranged in a NW-SE oriented facies belt that differs in thickness, age attribution and facies. The carbonate ramp facies passed into Transitional beds (including "Globigerina marls") and basin sediments (flysch). Tectonic influences associated with the ongoing orogen, sea-level changes, and warming events (Early Eocene Climate Optimum, EECO, and Middle Eocene Climate Optimum, MECO) had a major control on sedimentation. Thus, these sedimentary sequences are a reliable tool for studying biotic response to climate change for platform to basin assemblages. The multidisciplinary study includes the taxonomic classification of different fossil groups, microfacies and petrologic interpretation of the rocks and interpretation of the biodiversity of the foraminiferal assemblages, geochemical composition of the sediments, and isotopic analysis of different elements of the skeletons. The limestones, rich in larger benthic foraminifera (LBF), were deposited on the transient carbonate ramps. The successions are rarely complete in terms of depositional settings (missing outer ramp, Španiček et al. 2017; inner ramp, Ćosović et al. 2022) and very often stratigraphically incomplete (Ćosović et al. 2018), whereas the sediments are diagenetically altered. The LBF tests that contribute most to sediment production are recrystallized and cemented and therefore unsuitable for isotopic analysis. Great proportion of tests of the Bartonian (nummulitids of genus *Nummulites* and orthophragminids) LBF show traces of bioerosion, and in some cases, it is unclear when bioerosion occurred (burrowing traces in large orthophragminids follow the growth pattern). The morphology of the basin(s) was also strongly tectonic. The depth of the basin varies from NW (Lutetian) to SE (Bartonian), with estimates ranging from 900 – 1,200 m (Živković and Babić 2003) down to 1,800 m. The proportion of smaller benthic foraminifera follows this trend, as they are more abundant in sediments from the NW part and almost absent in sediments in the SE. This could be an indication of lower oxygen levels at the bottom of the basin due to increased stratification from warming. Unfortunately, planktonic tests, whether or not they occur in organic-rich marls, have always been recrystallized. Tests deposited near the EECO were also highly dissolved. Could this be the results of supra-lysoclinal dissolution or due to stratification? In shallower basins significant shoaling of the lysocline and thermocline follows local circulation patterns and local tectonics (Cramwinckel et al. 2020). The shallowing of the thermocline considered as a global event due to warming, resulted in the migration of certain species from their habitats, and the changes in their size (gigantism or dwarfism).

How then might we interpret the conditions? In addition to interpreting the microfacies interpretation using the standard criteria for carbonate environments, bulk-sediment geochemical analysis proved to be the key to interpreting conditions on the bottom. The ratio of certain elements indicates the intensity of weathering and terrestrial influx in carbonate environments.

Acknowledgement: The study of the Eocene deposits was funded by the Croatian Science Foundation (HRZZ) through Project IP-2019-04-5775 (BREEMECO).

References:

Ćosović, V., Mrinjek, E., Nemec, W., Španiček, J. & Terzić, K. 2018. Development of transient carbonate ramps in an evolving foreland basin. *Basin Research*, 30, 4, 746–765.

Ćosović, V., Aljinović, D., Bucković, D., Čančar, M., Felja, I., Galović, I., Horvat, M., Kurtanjek, D., Pejnović, I., Pezelj, Đ., Tomašić, N. & Ćorić, S. 2022. Preservation of *Nummulites* test in shallow-water limestones regarding the Middle Eocene Climate Optimum (Dinaric foreland basin, Croatia). EGU, General Assembly 2022, Vienna, Austria, 23-27 May, EGU22-2039, https://doi.org/10.5194/egusphere-egu22-2039, 2022

Cramwinckel, M. J., Coxall, H. K., Śliwińska, K. K., Molling, M., Harper, D. T., Bijl, P. K., Brinkhuis, H., Eldrett, J. S., Houben, A. J. P., Peterse, F., Schouten, S., Reichart, G. J., Zachos, J. C. & Sluijs, A. 2020. A Warm, Stratified, and Restricted Labrador Sea Across the Middle Eocene and Its Climatic Optimum. *Paleoceanography and Paleoclimatology*, 35, 10, 1–27.

Španiček, J., Ćosović, V., Mrinjek, E. & Vlahović, I. 2017. Early Eocene evolution of carbonate depositional environments recorded in the Čikola Canyon (North Dalmatian Foreland Basin, Croatia). *Geologia Croatica*, 70, 1, 11–25.

Živković, S. & Babić, Lj. 2003. Paleoeceanographic implications of smaller benthic and planktonic foraminifera from the Eocene Pazin basin (Coastal Dinarides, Croatia). *Facies*, 49, 1, 49–60.

Integrating field volcanology, paleomagnetism and structural geology to correlate a poorly preserved Miocene succession in the East Mátra Mts. (Hungary)

ZOLTÁN CSERI[1], EMŐ MÁRTON[2], MÁRTON PALOTAI[3]
MÁTYÁS HENCZ[1], TAMÁS BIRÓ[1] and DÁVID KARÁTSON[1]

1 – Eötvös University, Department of Physical Geography, Pázmány Péter stny. 1/C., 1117 Budapest, Hungary; e-mail: paleo@sztfh.hu

2 – Paleomagnetic Laboratory, SARA., Columbus u. 17-23., 1145 Budapest, Hungary

3 – Geology and Laboratory Department, SARA, Stefánia út. 14, 1143 Budapest, Hungary

From the early to late Miocene (between ca. 20 – 10 Ma: Hámor et al. 1978; Márton & Pécskay 1998; Lukács et al. 2021; Karátson et al. 2022), intense explosive silicic volcanism took place in the Carpatho-Pannonian Region. The pyroclastic deposits have been divided into three complexes based on their chemical and lithological properties (Szakács et al. 1998), simultaneously confirmed by paleomagnetism and K-Ar dating (Márton & Pécskay 1998; Márton et al. 2007). In the present study area, the pyroclastics have been mapped as belonging either to the Middle=MPC or to the Upper=UPC complex, although they have fairly similar macroscopic features (e.g. lithoclasts, pumices and phenocrysts). Several studies have focused on the large-scale stratigraphy of the Mátra Mts. (e.g., Varga et al. 1975), however, a detailed, modern field-based volcanological description is lacking for most areas. This is true both for the MPC (~30° CCW), which stretches from the West to the East Mátra, and for the UPC (0 – 10° CW) in the Tarna valley (eastern margin of the mountains).

Using a complex methodology, we focused on the stratigraphy of the widespread pumiceous dacitic lapilli tuff (genetically ignimbrite) with locally interbedded fallout pyroclastics (newly discovered layers), and the reworked volcanogenic sedimentary rocks that were deposited on the ignimbrites in an (at least partially) subaqueous environment. Correlation is complicated by the sporadic exposures and the complex structural geology of the area (Darnó Zone; Fodor et al. 2005), which results in similar layers occurring at various altitudes.

Beyond the detailed field descriptions, new paleomagnetic (14 sites) and structural geological measurements were made. The new and previously published paleomagnetic results from the study area are characterized by stable paleomagnetic signal on thermal demagnetization up to 575°C and invariably reversed polarity. In the geographical coordinate system, a few suggest moderate CCW, while the majority the lack of vertical axis rotation. Using the tilts observed in the field and/or the AMS foliation plane of the individual sites, between the sites direction-correction tilt test (Enkin 2003) was carried out with positive results proving the pre-tilting age of the magnetizations. As a consequence, the different site-mean directions became well grouped around 0 – 10° CW. Thus, paleomagnetism suggests that the sampled volcanic deposits belong to the same formation (UPC).

In summary, a detailed event stratigraphy of a volcanic succession has been compiled, incorporating reliable, corrected paleomagnetic results. The structural analysis confirmed at several places that the tilt corrections used for the paleomagnetic vectors were indeed correct. Beyond paleomagnetic correction, structural measurements also helped to constrain the stratigraphy, as faulting caused the repetition of units. Moreover, fallout layers, not described before, proved to be excellent horizons for correlation too, and, in addition, they provide a clear evidence of non-homogeneous (i.e. multiple) ignimbrite emplacement. We also concluded that the tectonic events clearly occurred after sedimentation, i.e. tilting did not occur during the primary volcanic events. This is supported by the originally horizontal sedimentation of epiclastics in subaqueous environments, moreover the directions of the flattened pumices in the ignimbrites, which coincide with the field-measured dip directions.

Acknowledgement: This work was supported by the Hungarian Scientific Research Fund projects no. K131894 and K128625.

References:

Enkin, R.J. 2003. The direction-correction tilt test: an all-purpose tilt/fold test for paleomagnetic studies. *Earth and Planetary Science Letters*, 212, 151–166.

Fodor, L., Radócz, Gy., Sztanó, O., Koroknai, B., Csontos, L. & Harangi, Sz. 2005. Post-Conference Excursion: Tectonics, Sedimentation and Magmatism along the Darnó Zone. *GeoLines*, 19, 141–161.

Hámor, G., Ravaszné Baranyai, L., Balogh, K. & Árváné Soós, E. 1978. A magyarországi miocén riolittufa-szintek radiometrikus kora. *MÁFI évi jelentése*, Budapest, 65–72.

Karátson, D., Biró, T., Portnyagin, M., Kiss, B., Paquette, J-L., Cseri, Z., Hencz, M,, Németh, K., Lahitte, P., Márton, E., Kordos, L., Józsa, S., Hably, L., Müller, S. & Szarvas, I. 2022. Large-magnitude (VEI ≥ 7) 'wet' explosive silicic eruption preserved a Lower Miocene habitat at the Ipolytarnóc Fossil Site, North Hungary. *Scientific Reports*, 12, 1, 9743.

Lukács, R., Guillong M., Bachmann O., Fodor, L. & Harangi, Sz. 2021. Tephrostratigraphy and Magma Evolution Based on Combined Zircon Trace Element and U-Pb Age Data: Fingerprinting Miocene Silicic Pyroclastic Rocks in the Pannonian Basin. *Frontiers in Earth Science*, 9, 1–20.

Márton, E. & Pécskay, Z. 1998. Complex evaluation of paleomagnetic and K/Ar isotope data of the Miocene ignimbritic volcanics in the Bükk Foreland, Hungary. *Acta Geologica Hungarica*, 41, 467–476.

Márton, E., Márton, P. & Zelenka, T. 2007. Paleomagnetic correlation of Miocene pyroclastics of the Bükk Mts and their forelands. *Central European Geology*, 50, 47–57.

Szakács, A., Márton, E., Póka, T., Zelenka, T., Pécskay, Z. & Seghedi I. 1998. Miocene acidic explosive volcanism in the Bükk Foreland, Hungary: Identifying eruptive sequences and searching for source locations. *Acta Geologica Hungarica*, 41, 413–435.

Varga, Gy., Csillagné Teplánszky, E. & Félegyházi, Zs. 1975. *A Mátra hegység földtana*. MÁFI évkönyv LVII/1, Budapest. 575 pp.

Deltaic coarse-grained deposits of the northern Vienna Basin: (re)interpretation of older data and cross-border correlation

TAMÁS CSIBRI[1], ĽUBOMÍR SLIVA[1], ANDREJ RUMAN[2], NATÁLIA HLAVATÁ HUDÁČKOVÁ[2], MICHAL JAMRICH[2], KATARÍNA ŠARINOVÁ[3] and MICHAL KOVÁČ[2]

1 – NAFTA a.s., Exploration and Production, Plavecký Štvrtok 900, 900 68 Plavecký Štvrtok, Slovak Republic; e-mail: tamas.csibri@nafta.sk

2 – Department of Geology and Paleontology, Faculty of Natural Sciences, Comenius University Bratislava, Mlynská dolina, Ilkovičova 6, 842 15 Bratislava, Slovak Republic

3 – Department of Mineralogy and Petrology, Faculty of Natural Sciences, Comenius University Bratislava, Mlynská dolina, Ilkovičova 6, 842 15 Bratislava, Slovak Republic

The cross-border correlations of the Miocene lithostratigraphic units (Slovakia, Austria) remain poorly constrained, owing to the various sources of clastic material transported into the basin and the low stratigraphic resolution of conglomerates. Therefore, this study is focused on the Lower and Middle Miocene conglomerates in the deltaic systems of the northern Vienna Basin and assesses their implications for cross-border correlations, as well as for the evolution of the Eastern Alpine – Western Carpathians junction area. The mutual relationships of alluvial plains, deltas, littoral and neritic areas of the basin was/is discussed to be triggered by sea-level changes. Based on the sedimentary environment evaluation and the possibilities of creating an accommodation space by tectonic subsidence, or its loss by increased input of clastics by deltas it can be stated that only partial comparison between the global and regional sea-level changes is possible.

The Lower Miocene sedimentary record of the older, wedge-top basin, which lasted from the latest Eggenburgian/Ottnangian to the Karpatian, contains several conglomerate bodies. In addition to the basal conglomerates of the Lužice Fm. (Kováč 2000), marginal conglomerate bodies were developed in the NE. Owing to the lack of geochronological and biostratigraphic data, these marginal Planinka Fm. and Jablonica Mb. of the Lakšáry Fm. were poorly constrained in terms of the lithostratigraphic classification. Based on the depositional mechanism and clast composition, the Otnangian-Karpatian conglomerates from the NE margin of the VB belong to a single depositional system grouped to the Jablonica deltaic system. Marginal alluvial to deltaic Jablonica Mb. vertically and laterally passes to offshore turbidites of the Prietž Mb. of the Lakšáry Fm. (Teťák 2017) that were deposited up to the end of the Karpatian. A braided river, as well as alluvial to delta plain sediments of the Gänserndorf Mb. of the Aderklaa Fm. were deposited in the southern part. These coarse-grained fluvial sediments prograde from the SW towards the NE (e.g., Weissenbäck 1995; Harzhauser et al. 2020). In the Slovak part of the VB, the alluvial to fluvial conglomerates proceed along its eastern margin. In contrast to the clasts of the Gänserndorf Mb. sourced in the Eastern Alps, conglomerates at the base of the Zohor-1 well were derived from the Western Carpathian complexes. They represent the temporal equivalent of the Jablonica Mb. and the Gänserndorf Mb. Conglomerates. The overlying heterolithic flood plain of the deltaic sediments from the Závod Fm. most likely form the facies continuation of the alluvial to flood plain deposits of the Schönkirchen Mb. (upper part of the Aderklaa Fm.).

The Middle Miocene sedimentation starts during a period of erosion enhanced by tectonics and followed by the filling-up of canyons incised in the older deposits, mainly Karpatian age (Siedl et al. 2020). In general, the Badenian deposition starts with terrestrial sediments along the slopes of the Malé Karpaty Mts. dated to 15.2 Ma. Later, along with the Devínska Nová Ves fan-delta, the presence of *Orbulina suturalis* developed in the marginal parts of the Vienna Basin during the Early Badenian. Despite having the same structural position, it is younger than the Rothneusiedl Formation in the southern part of the Vienna Basin. The provenance of clastics reflects the source in the Central Western Carpathian units and documents the Miocene uplift of the horst structure of the Malé Karpaty Mts.

Acknowledgement: This research is a result of several years of research, which during these years was supported by the Slovak research and development agency under contracts No. APVV-16-0121, APVV-20-0120, APVV-20-0079, VEGA- 1/0526/2 and VEGA-2/0013/20. Our appreciation goes to the management of Nafta a.s. for allowing access to well core repositories well data sheets.

References:

Harzhauser, M., Kranner, M., Mandic, O., Strauss, P., Siedl, W. & Piller, W.E. 2020. Miocene lithostratigraphy of the northern and central Vienna Basin (Austria). *Austrian Journal of Earth Science*, 113, 169–200.

Kováč, M. 2000. *Geodynamic, paleogeographic and structural evolution of the Carpathian-Pannonian region in Miocene – A new view on the Neogene basins of Slovakia.* Veda, Bratislava. 204 pp. (in Slovak).

Teťák F. 2017: Neogene sediments between Podbranč and Hradište pod Vrátnom, Vienna Basin. *Acta Geologica Slovaca*, 9, 1, 1-14.

Weissenbäck M. 1995. Ein Sedimentationsmodell für das Unterbis Mittelmiozän Karpatien-Badenien des zentralen Wiener Beckens. Dissertation. *Geologischen Institut der Universität* Wien, 1–154.

Miocene volcanism in the Slovenský Raj Mts.: Magmatic, space and time relationships in the Western Carpathians

RASTISLAV DEMKO[1], MARIÁN PUTIŠ[2], LUKÁŠ ACKERMAN[3], QIU-LI LI[4], DAVID CHEW[5] and ONDREJ NEMEC[2]

1 – State Geological Institute of Dionýz Štúr, Mlynská dolina 1, SK-817 04 Bratislava, Slovak Republic; e-mail: rastislav.demko@geology.sk

2 – Department of Mineralogy, Petrology and Economic Geology, Faculty of Natural Sciences, Comenius University, SK-84215 Bratislava, Slovak Republic

3 – Institute of Geology of the Czech Academy of Sciences, CZ-165 00 Prague, Czech Republic

4 – State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China

5 – Department of Geology, School of Natural Sciences, Trinity College Dublin, College Green, Dublin 2, Ireland

The products of Miocene volcanic activity in the Slovenský Raj Mts., Middle Slovakia, are in the Lesnica Valley located SE of Čingov (Novotný and Tulis 2005). Magmatic rocks comprise a volcanic intrusive complex represented by a swarm of feeder dikes and sporadic relics of hyaloclastite lavas. They intruded a complex of the Triassic Bodvaszilas sandstones and carbonates of the Silica Nappe

The subvolcanic bodies of feeder dike complex are doleritic basalts of sub-ophitic to intersertal texture, while the effusive rocks are hyaloclastites. The main rock-forming igneous minerals are clinopyroxene, plagioclase and Fe-Ti oxides, in association with Chl+Act+Mt+Ttn ± Cc ± Ep.

The interstitial rock spaces are filled with the micropoikilitic Cpx+Ab+TiMt association, which represents the solidification product of residual interstitial melt due to the increasing effects of supercooling and rapid quenching.

In the basalts, fragments of syn-eruptically incorporated carbonates are observed. Vesicular and amygdaloidal textures are observed due to magmatic degassing.

Compositionally, the igneous rocks correspond to subalkaline basalts and basaltic andesites of the tholeiite differentiation series, accompanied by alkaline basalts, trachybasalts and basaltic trachyandesites. Petrological study shows that the erupted products are the result of magmatic differentiation of the parent basaltic tholeiitic magma with redox ΔQFM = +1 to +3, affected by varying degrees of 0 – 50 % fractionation accompanied by the assimilation of carbonate material in a common shallow magmatic reservoir. The tectonic stress of the magmatic reservoir resulted in the extraction of magma, with intrusive pulses into the surrounding country rock, where it sometimes erupted into lava.

REE geochemistry of basaltic rocks from the Lesnica Valley are characterized by NMORB-type patterns with $La/Yb_c \leq 1$ (1.01 – 0.76) and $La/Sm_c<1$ (0.88 – 0.68) at near constant Eu/Eu* (0.89 – 0.85). NMORB like character is also supported by depleted isotopic values of $^{143}Nd/^{144}Nd$ with $\varepsilon Nd_{(13)}$ = +8.0 or +7.8. On the other hand, a significant difference, namely $Sm/Yb_c \geq 1$ (1.30 – 1.04) and $Gd/Yb_c \geq 1$ (1.3 – 1.1) compared to classical NMORB-OIB ocean basalts indicates important differences. The analyzed REE values can be modeled by 1 % fractional melting of garnet peridotite mixed in 1:9 with melts from 7 % melting of spinel peridotite of PM composition.

A geochronological study based on SIMS (in Beijing) and LA-MC-ICP-MS (in Dublin) U/Pb analysis of separated zircons from two separate subvolcanic bodies yielded concordant age of 12.69±0.24 Ma and 13.3±0.16, placing magmatic activity in the Lesnica Valley in the Serravallian period. The middle Miocene age links in with volcanic activity in the wider Western Carpathians, specifically volcanic activity progressing from west to east in the zone of Outer Western Carpathians (OWC), with the first activity in Moravia at 13.5 Ma, then Pieniny at 13.3 Ma, and next Ladomirov at 12.4 Ma (Pécskay et al. 2006). The first determined volcanic manifestation in the Lesnica Valley is therefore synchronous with the beginning of volcanic activity in the Pieniny Klippen Belt because of tectonic interaction between the colliding ALCAPA microplate and the southern margin of the European platform. It preceded the main volcanic activity in the Slánske vrchy volcanic chain of 12±0.9 Ma towards the east and the volcanic activity of the Vepor stratovolcano of 12.28 – 11.56 Ma (Konečný et al. 2015) towards the southwest. The timing of magmatic activity in the Lesnica Valley is coeval with the NE-directed maximal compression in the OWC Flysch Zone (Nemčok et al. 1998) and NW-SE trending extension in the Slovenský Raj Mts. during the Serravallian (Nemčok et al. 1998; Kováč et al. 2017).

The geochemical NMORB-like character of basaltic rocks, otherwise atypical for the Miocene volcanic rocks from the Western Carpathians (Harangi et al. 2007) and the age of magmatic activity from the Lesnica Valley are consistent with extensional tectonic processes in the Middle Miocene which took place in the wider area of the Slovenský Raj Mts.

References:

Kováč, M., Márton, E., Vojtko, R., Hók, J., Králiková, S., Plašienka, D., Klučiar, T., Hudáčková, N. & Oszczypko-Clowes, M. 2017. Neogene palaeogeography and basin evolution of the Western Carpathians, Northern Pannonian domain and adjoining areas. *Global and Planetary Change*, 155, 133–154.

Konečný, V., Konečný, P., Kubeš, P. & Pécskay, Z. 2015. Paleovolcanic reconstruction of the Neogene Vepor stratovolcano (Central Slovakia), part 1. *Mineralia Slovaca*, 47, 1–76.

Harangi, S., Downes, H., Thirlwall, M. & Gmeling, K. 2007. Geochemistry, petrogenesis and geodynamic relationships of Miocene calc-alkaline volcanic rocks in the Western Carpathian Arc, Eastern Central Europe. *Journal of Petrology*, 48, 2261–2287.

Novotný, L. & Tulis, J. 2005. Nové geologické objekty v Slovenskom raji. *Mineralia Slovaca*, 37, 91–92.

Pécskay, Z., Lexa, J., Szakács, A., Seghedi, I., Balogh, K., Konečný, V., Zelenka, T., Kovács M., Póka, T., Fulop, A., Márton, E., Panaiotu, C. & Cvetković, V. 2006. Geochronology of Neogene-Quaternary magmatism in the Carpathian arc and Intra-Carpathian area: a Review. *Geologica Carpathica*, 57, 511–530.

Comparison of pollen spectra and fossilized woods from the Oligocene and Middle Miocene sediments of Central Paratethys area – southern part of the Czech Republic (Moravia) - palaeoecological case studies

NELA DOLÁKOVÁ[1], DAVID KREJČÍŘ[1], TORSTEN UTESCHER[2,3], MARIANNA KOVÁČOVÁ[4], VLADIMÍR GRYC[5] and JAKUB SAKALA[6]

1 – Department of Geological Sciences, Faculty of Science, Masaryk University, Brno, Czech Republic; e-mail: nela@sci.muni.cz

2 – Senckenberg Research Institute and Natural History Museum/Biodiversity and Climate Research Centre, Frankfurt, Germany

3 – Steinmann Institute, Bonn University, Bonn, Germany

4 – Department of Geology and Palaeontology, Faculty of Natural Sciences, Comenius University in Bratislava, Bratislava, Slovak Republic

5 – Department of Wood Science, Faculty of Forestry and Wood Technology, Mendel University of Agriculture and Forestry in Brno, Czech Republic

5 – Institute of Geology and Palaeontology, Faculty of Science, Charles University, Praha, Czech Republic

Palynospectra from sediments of the Czech and Slovak parts of Central Paratethys (over 40 sites and boreholes) from Oligocene to Upper Miocene age have been studied. Number of localities with petrified woods are also known from this area. However only one locality contained both types of fossils together (Loučka - Middle Oligocene). Most findings from river terraces do not allow the age determination. Based on detailed systematic study and ecological characteristics, we try to find commonalities of these fossil groups. Composition of pollen spectra studied by the LM/SEM combination method was confronted with sets of collected woods.

The sediments of the Carpathian foredeep and the sediments of the menilitic assemblage of the Silesian unit of the flysch zone are considered as the assumed source of silicified woods. Main climatic character of the studied timespan comprises Late Oligocene Warming (27 – 26 Ma), Miocene Climatic optimum MCO (17 – 15 Ma) highest values in the global oxygen stack at ca. 15.5 – 15.0 Ma (Zachos et al. 2001) followed by gradual cooling Miocene climatic transition (MCT) at 14.8 – 12.0 Ma (Jirman et al. 2019; Zachos et al. 2001; Doláková et al. 2021). The landscape evolution during the Oligo-Miocene was characterized by pulling up of the flysh nappes (up to the Badenian (Lower Langhian)) and uplift of the Carpathian mountain chain and subsidence of adjacent lowlands. In addition to climatic changes, the vegetation was also affected by the initiation of altitudinal zonation.

Main climatic parameters of palynospectra were interpreted using Coexistence approach (Doláková et al. 2021). Gradual cooling from Subtropical Broadleaved-Evergreen forests to Warm-temperate Mixed-Mesophytic forest with variously intense cyclic variations were documented (Kováčová et al. 2011). These are represented by very warm conditions with low seasonality and overall humid conditions in earlier part of the MCO. Subsequent cooling was manifested as an increasing of seasonality, existence of short-term dry phases and decreasing of mean annual temperatures and main temperatures of the coldest month.

Studied fossil woods from two sites are taxonomically similar (deciduous and evergreen oaks such as *Quercus* and *Lithocarpus*, less *Castanea*, *Platanus*, *Ulmus* or *Salix*, *Taxodium*, *Palm* trees). Two exceptions were noted. There are fossil woods resembling anatomical structure similar to wood of *Mangifera* in the group of Oligocene woods, while they are absent in the group of Miocene ones. *Albizia*-like wood newly appears just in group of Miocene woods. In general, it is possible to distinguish the studied silicified woods on the basis of different anatomical features: a different record of tree rings or the presence of early and late wood. Based on these properties, they can be divided into two groups that indicate growth in different climatic conditions. In comparison with the climatic record from palynological spectra, these collections can be preliminarily classified as phases with a warmer (probably original source of Přerov wood collection – Middle Oligocene Menilite Formation) and slightly colder climate (probably original source of Žabčice wood collection – Middle Miocene coastal sediment of Carpathian foredeep) in the time span of the Oligocene to Middle Miocene.

References:

Doláková, N., Kováčová, M. & Utescher, T. 2021. Vegetation and climate changes during the Miocene climatic optimum and Miocene climatic transition in the northwestern part of Central Paratethys. *Geological Journal*, 56, 729–743.

Jirman P., Geršlová E., Bubík M., Sachsenhofer R.F., Bechtel A. & Więcław D. 2019. Depositional environment and hydrocarbon potential of the Oligocene Menilite Formation in the Western Carpathians: A case study from the Loučka section (Czech Republic). *Marine and Petroleum Geology*, 107, 334–350.

Kováčová, M., Doláková, N. & Kováč, M. 2011. Miocene vegetation pattern and climate change in the northwestern Central Paratethys domain (Czech and Slovak Republic). *Geologica Carpathica*, 62, 251–266.

Zachos, J., Pagani, M., Sloan, L., Thomas, E. & Billups, K. 2001. Trends, rhythms, and aberrations in global climate 65 Ma to present. *Science*, 292, 686–693.

Geological structure and structural evolution of the Tatric Unit in the Devínska Kobyla massif (Malé Karpaty Mts.)

DAVID MILOŠ DROPPA, RASTISLAV VOJTKO, JOZEF HÓK, KATARÍNA KRIVÁŇOVÁ, ALEXANDER LAČNÝ and SILVIA GERÁTOVÁ

Department of Geology and Paleontology, Faculty of Natural Sciences, Comenius University in Bratislava

The Devínska Kobyla massif is located on the southwestern border of Malé Karpaty Mts. and is adjacent to the Vienna basin to the west and the Danube Basin to the east. The study area contains the Tatric crystalline basement, Devín cover succession and Borinka Unit (Polák et al., 2012).

The Tatric Unit is composed particularly of the crystalline basement and the Permian – Mesosoic cover succession. The largest part of the studied area is composed of different variants of granitoid rocks of the Bratislava massif. They are situated in the central and east parts of the area. Towards the northwest, metamorphic rocks of the Pezinok and Pernek groups are progressively appearing (Ivan & Méres, 2006). The Upper Devonian to Lower Carboniferous granitoid rocks were intruded into these metamorphic rocks (Kohút et al., 2009; Kohút & Larionov, 2021). The Tatric crystalline basement is covered by the Permian to Lower Triassic coarse-grained siliciclastic deposits and Triassic carbonates of the Devín succession.

On the west border of the studied area, the Jurassic and Cretaceous formations are preserved in inverse positions. In the most north part of the Devínska Kobyla hill, Jurassic carbonates of the Borinka Unit (Infratratricum) appear from below the Tatric crystalline basement (Plašienka & Putiš, 1987).

Based on the structural analysis, the rocks of the Tatric Unit were deformed during several tectonic phases. The oldest deformation phase is considered to be Variscan deformation D_1^V, which is preserved only as rootless folds of planar structures S_1^V. Structures of the D_2^V deformation phase, which represent flattening during the main Variscan deformation are defined by pervasive metamorphic foliation S_2^V directed to the northwest with top-to-the-southeast tectonic transport indicated also by mineral and stretching lineations L_2^V. These structures are preserved only in the Variscian metamorphosed rocks of the Pernek and Pezinok groups.

Sedimentary rocks of the Devín cover succession and the Borinka Unit have preserved primary bedding planes S_0^A. Primary planar structures are often enhanced by flattening during the Alpine deformation phase (D_1^A).All earlier structures are partly overprinted by Alpine (Cretaceous) foliations S_2^A, which belong to the D_2^A deformation phase with a southeast inclination and top-to-the-northwest direction of movement. Moreover, the sedimentary rocks of the Devín succession and metamorphosed rocks of the Pernek and Pezinok groups are folded and on some placed recumbent folds were formed. The youngest Alpine structures are represented by spaced cleavage surfaces S_3^A.

Acknowledgement: The study was supported financially by the Slovak Research and Development Agency (APVV) under contracts Nos. APVV-17-0170, APVV-20-120, and APVV-21-0281.

References:

Polák M., Plašienka D., Kohút M., Putiš M., Bezák V., Maglay J., Olšavský M., Havrila M., Buček S., Elečko M., Fordinál K., Nagy A., Hraško Ľ., Németh Z., Malík P., Liščák P., Madarás J., Slavkay M., Kubeš P., Kucharič Ľ., Boorová D., Zlinská A., Siráňová Z. & Žecová K. 2012: *Vysvetlivky ku geologickej mape Malých Karpát (M 1:50 000).* Štátny geologický ústav Dionýza Štúra, Bratislava, 287 pp.

Ivan, P. & Méres, Š. 2006: Litostratigrafické členenie a pôvod staropaleozoickej časti kryštalinika Malých Karpát – nový pohľad na základe výsledkov geochemického výskumu. *Mineralia Slovaca*, 38, 165–186.

Kohút M. & Larionov A.N. 2021: From subduction to collision: Genesis of the Variscan granitic rocks from the Tatric Superunit (Western Carpathians, Slovakia). *Geologica Carpathica*, 72, 2, 96–113.

Kohút M., Uher P., Putiš M., Ondrejka M., Sergeev S., Larionov A. & Paderin I. 2009: SHRIMP U-Th-Pb zircon dating of the granitoid massifs in the Malé Karpaty Mountains (Western Carpathians): evidence of Meso-Hercynian successive S- to I-type granitic magmatism. *Geologica Carpathica*, 60, 5, 345–350.

Plašienka D. & Putiš M. 1987: Geological structure of the Tatricum in the Malé Karpaty Mts. *In: Structural Development of the Carpathian - Balkan Orogenic Belt*. GÚDŠ, Bratislava, 47–82.

Plašienka D., Michalík J., Kováč M., Gross P. & Putiš M. 1991: Paleotectonic evolution of the Malé Karpaty Mts. – an overview. *Geologica Carpathica*, 42, 4, 195–208.

Scale-dependent definition of syn-rift and post-rift phases during the extension of the Pannonian Basin: inferences from numerical modelling, stratigraphic and tectonic data

LÁSZLÓ FODOR[1,2], ÉVA ORAVECZ[1,3] and ATTILA BALÁZS[3]

1 – Eötvös Loránd University, Institute of Geography and Earth Sciences, Department of Geology, Budapest, Hungary; e-mail: lasz.fodor@yahoo.com

2 – Eötvös Loránd Research Network, Institute of Earth Physics and Space Science, Sopron, Hungary

3 – ETH Zürich, Department of Earth Sciences, Zürich, Switzerland

The classical model of McKenzie (1978) and followers (e.g., Royden and Keen 1980) defined an instantaneous extensional event followed by a thermal cooling phase as syn-rift and post-rift stages. While the former comprises crustal and mantle thinning, the latter should be characterised by the lack (paucity) of crustal faulting and extensional ductile shearing, but persisting subsidence. The syn-rift phase should be characterized by increase of heat flow, elevation of the Moho and the lithosphere-asthenosphere boundary (LAB) and formation of asthenospheric dome while the post-rift phase is marked by progressive cooling of the entire mantle.

Because of these contrasting characteristics, the boundary of the syn- and post-rift phases is important and thus represented a continuous debate through the last decades of research in the Pannonian Basin (PB). The suggested timing span ranges from early Middle Miocene to earliest Late Miocene depending on authors and location of the study (Tari 1994; Horváth et al. 2015; Balázs et al. 2016).

Recent advances in stratigraphy, structural analyses and particularly numerical modelling can potentially lead to better understanding the deep earth processes, their role in near-surface deformation and thus basin formation. Revised and new data across the PB revealed that the first preserved sediments and associated faulting in different Pannonian sub-basins show a NE-ward younging from the western and southern basin margins toward the basin centre. Similarly, the cessation of crustal faulting seems to show the same trend. Thus, the change from fault-dominated to non-faulted basin evolution (the syn- to post-rift boundary) has different timing in the western than in the central PB. Thus, a common date of change for the entire PB cannot be given.

Two solutions seem to be plausible: one can speak about a sub-basin scale definition of the syn-rift to post-rift boundary; in this scenario one can speak about onset and cessation of crustal faulting or lithospheric extension or using the term "syn-rift" in local scale. The other solution would be to define a basin-wide timing corresponding to the youngest possible time of change from faulting to post-faulting phases, that seems to be around 9Ma in the SE PB, namely in the Makó trough.

The numerical modelling clearly emphasize the importance of deep earth processes in crustal faulting and subsidence. This means that faulting and extension is just an expression of mantle flows varying in time and dimension. The processes in the sub-basins is mainly governed by the evolution of underlying mantle flows determined themselves by the physical parameters of the mantle and the evolution of flow cells and additional boundary constraints, like inherited weakness zones (Balázs et al. 2017, 2018). The margin-to-centre sub-basin migration is unequivocally predicted by numerical models with varying dimensions; this seems to be the nature of extension, at least in the PB (Balázs et al. 2017, Fodor et al. 2021). Examples of steps and characters "unpredicted" by the classical models include, among others, the (1) larger-than-predicted post-rift subsidence; (2) "inversion" at the end of Middle Miocene, (3) Late Miocene uplift instead of subsidence in the Styrian basin, etc.; all are present in numerical modelling.

These observations suggest that we should change our way of thinking; mantle processes, and particularly their dynamic characters, are the primary forces governing crustal extension and related subsidence, and these forces are able to "overwrite" the subsidence tendency predicted from classical syn-rift to post-rift models.

Acknowledgement: The researches behind the presentation are supported by the National Research, Development and Innovation Office under the project 134873.

References:

Balázs, A., Mațenco, L., Magyar, I., Horváth, F. & Cloetingh, S. 2016. The link between tectonics and sedimentation in back-arc basins: New genetic constraints from the analysis of the Pannonian Basin. *Tectonics,* 35, 1526–1559.

Balázs, A., Burov, E., Matenco, L., Vogt, K., Francois, T. & Cloetingh, S. 2017. Symmetry during the syn- and post-rift evolution of extensional back-arc basins: the role of inherited orogenic structures. *Earth Planetary Science Letters,* 462, 86–98.

Balázs, A., Maţenco, L., Vogt. K., Cloetingh, S. & Gery, T. 2018. Extensional polarity change in continental rifts: inferences from 3-D numerical modeling and observations. *Journal of Geophysical Research: Solid Earth,* 123, 8073–8094.

Fodor, L., Balázs, A., Csillag, G., Dunkl, I., Héja, G., Jelen, B., Kelemen, P., Kövér, Sz., Németh, A., Nyíri, D., Selmeczi, I., Trajanova, M., Vrabec, M. & Vrabec, M. 2021. Crustal exhumation and depocenter migration from the Alpine orogenic margin towards the Pannonian extensional back-arc basin controlled by inheritence. *Global and Planetary Change,* 201, 103475.

Horváth, F. Musitz, B., Balázs, A.,Végh, A. Uhrin, A. Nádor, A. Koroknai, B., Pap, N., Tóth, T. & Wórum, G. 2015: Evolution of the Pannonian basin and its geothermal resources. *Geothermics,* 53, 328–352.

McKenzie, D. 1978. Some remarks on the development of sedimentary basins. *Earth and Planetary Science Letters*, 40, 25–32.

Royden, L. & Keen, C.E. 1980. Rifting process and thermal evolution of the continental margin of Eastern Canada determined from subsidence curves. *Earth and Planetary Science Letters,* 51, 2, 343–361.

Tari, G. 1994. *Alpine Tectonics of the Pannonian basin*. PhD. Thesis, Rice University, Texas, USA. 501 pp.

Preliminary 3D integrated geophysical model of the Tatra Mts and its surroundings

DOMINIKA GODOVÁ[1,2], MIROSLAV BIELIK[1,2], JÁN VOZÁR[1], JAROSLAVA PÁNISOVÁ[1], JANA DÉREROVÁ[1] and VLADIMÍR BEZÁK[1]

1 – Earth Science Institute, Slovak Academy of Sciences, Dúbravská cesta 9, P. O. Box 106, 840 05 Bratislava, Slovak Republic; e-mail: geofdogo@savba.sk

2 – Department of Engineering Geology, Hydrology and Applied Geophysics, Faculty of Natural Sciences, Comenius University, Ilkovičova 6, 842 15 Bratislava 4, Slovak Republic

The complex tectonic structure of the Western Carpathians and their tectonic evolution has been a topic of discussions for a long time. Geophysical methods can contribute significantly to broaden the knowledge regarding the deep structure of the region, but also regarding the contact zone of the Western Carpathians with surrounding tectonic units, or the contact of the individual tectonic units of the Western Carpathians.

This work deals with a 3D integrated geophysical modelling of the Tatra Mts area by means of the IGMAS+ (Interactive Gravity and Magnetic Application System) software. The area was selected for the noticeable differences in available data from multiple geophysical methods, which are not fully clarified yet. Their interpretation indicates differences in the physical properties of the Tatric crystalline units in the Tatra Mts.

The preliminary density model is based on gravity data, as well as the seismic, and magnetotelluric data and their interpretations. Physical properties of modelled bodies, the densities in this case, were mostly calculated for the deeper parts of the model. For this purpose, the seismic velocities were transformed using the formulas that consider the change of the pressure-temperature conditions in depth. The deep structure of the model, namely the Moho and the lithosphere-asthenosphere boundary (LAB), were modelled according to results of the international seismic projects in the Central Europe. The surface geological structure was used for the division of the surface bodies and their densities were defined based on the results from laboratory measurements on surface and borehole rock samples, and from well-logging.

The results of the modelling can bring new information not only on the geological structure of the Tatra Mts and its response in different geophysical fields, but it can also clarify the tectonic evolution of the region and interactions of the Western Carpathian tectonic units during these processes.

Acknowledgement: This work was supported by the Slovak Research and Development Agency under the contracts No. APVV-16-0146, APVV-16-0482, APVV-21-0159 the VEGA Slovak Grant Agency under project No. 2/0006/19, 2/0047/20, and the SAS grants for PhD students under application No. APP0313. The study was also investigated in the frame of the ILP (CoLiBrI), and the Adria Array projects.

The paleogeography of the Złatne Basin (Pieniny Klippen Belt)

JAN GOLONKA and ANNA WAŚKOWSKA

Faculty of Geology, Geophysics and Environmental Protection, AGH University of Science and Technology, ul. Mickiewicza 30, 30-059 Kraków, Poland; e-mail: jgolonka@agh.edu.pl

Sikora, (1971) described the Złatne Succession having the type locality in Złatne Mountain in Pieniny Klippen Belt (PKB), Poland. Paleogene flysch deposits are exposed in this area. Albian–Neogene flysch follows condensed deep-water Jurassic–Lower Cretaceous rocks, mainly radiolarites and pelagic cherty limestones. The flysch contains olistoliths and represent the sedimentary mélange. The Złatne Succession was deposited in the deepest part of the Złatne Basin (ZB) (Golonka and Krobicki 2004) that constituted the southeastern branch of Alpine Tethys (Fig. 1). Czorsztyn, Czertezik, Niedzica, Pieniny and Branisko successions (Birkenmajer, 1977) were deposited on the north-western slope of this basin. The Slovak PKB Klape, Manín, Kostelec, Streženice, Drietoma, Fodorka, Nižná, Chotúč, Stupné, Hoština, Dúbravka, Michalova Hora successions perhaps are linked to the south-eastern slope, but their position is speculative (Golonka et al. 2019).

ZB originated as a result of emergence of the Czorsztyn Ridge dividing the Alpine Tethys in the Middle Jurassic. It existed as an basin located between Central Carpathian Plate and Czorsztyn Ridge during Jurassic–Early Cretaceous times (Fig. 1). The subduction initiated at the margin of the Central Carpathian Plate triggering its movement in the Albian and developing the accretionary prism within ZB. This wedge reached and overrode the Czorsztyn Ridge during the latest Cretaceous–Paleocene times. The turbiditic and pelagic sedimentation continued in the piggy-back setting until Neogene times. Finally, the ZB and accretionary prism deposits were transformed into Złatne Unit (nappe).

Recently, the Złatne Unit is best exposed in the Spisz Pieniny Mountains in Poland as well as in the Haligovce – Vel'ký Lipník area in Małe Pieniny Mountains in Slovakia. The huge olistoliths in Haligovce – Vel'ký Lipník area represent mainly shallow water sequences of the southwestern margin of Alpine Tethys. These olistoliths are surrounded by Upper Cretaceous and Paleogene flysch sequences.

Acknowledgement: This research was financially supported by the Polish National Science Center grant NCN – 2019/35/B/ST10/00241.

References:

Birkenmajer, K. 1977. Jurassic and Cretaceous lithostratigraphic units of the Pieniny Klippen Belt, Carpathians, Poland. *Studia Geologica Polonica*, 45, 2, 1–159.

Golonka, J. & Krobicki M. 2004. Jurassic paleogeography of the Pieniny and Outer Carpathian basins. *Rivista Italiana di Paleontologia e Stratigrafia*, 110, 5–14.

Golonka, J., Pietsch, K., Marzec, P., Kasperska M., Dec J., Cichostępski K. & Lasocki S., 2019. Deep structure of the Pieniny Klippen Belt in Poland. *Swiss Journal of Geosciences*, 112, 475–506.

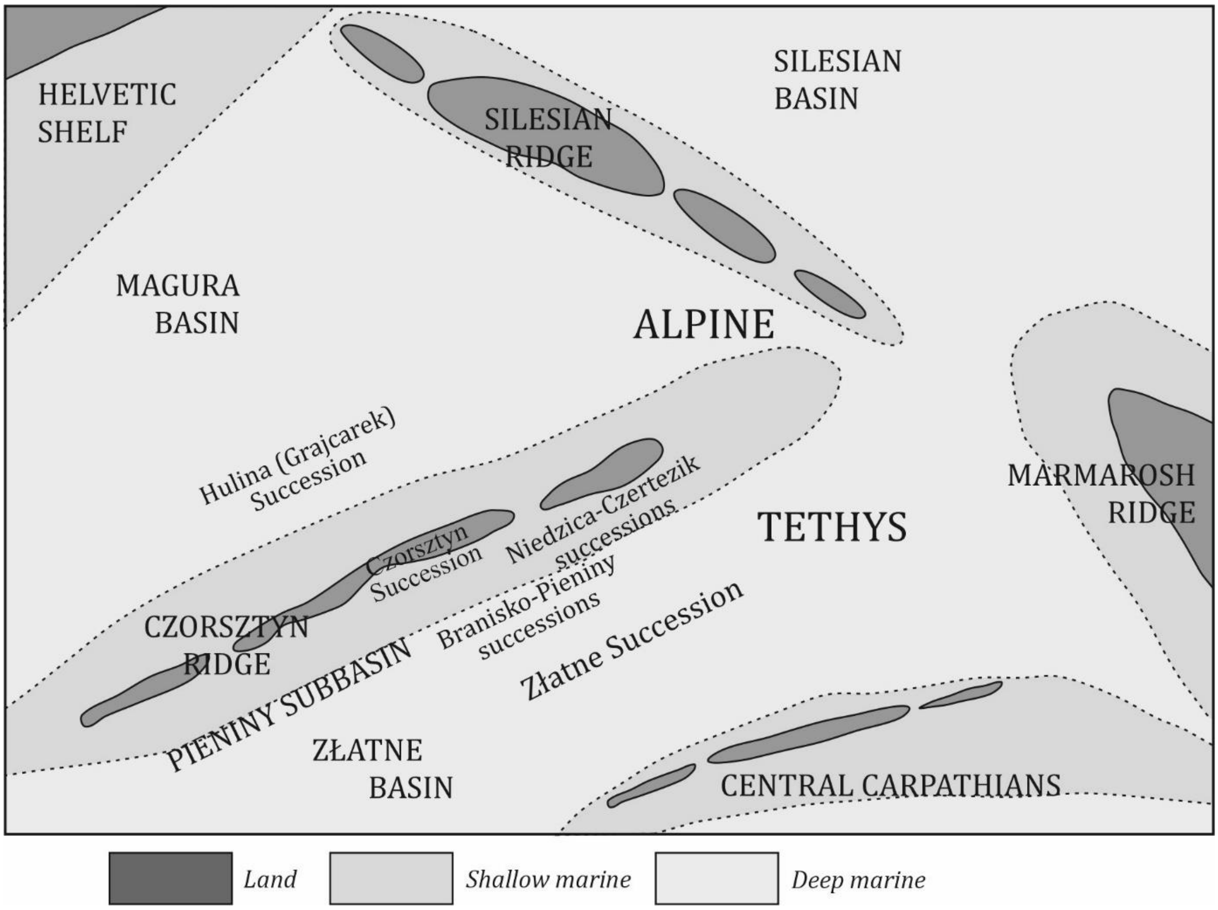


Figure 1: Early Cretaceous Złatne Basin within the Alpine Tethys.

Do we have enough evidence to prove the oldest environmental change in the area of the Papuk mountain (North Croatian Basin) in the Early Miocene?

VALENTINA HAJEK TADESSE[1], LARA WACHA[1], MARIJA HORVAT[1], INES GALOVIĆ[1], KORALJKA BAKRAČ[1], ANITA GRIZELJ[1]1, OLEG MANDIĆ[2] and BETTINA REICHENBACHER[3]

1 – Croatian Geological Survey, Sachsova 2, 10 000 Zagreb, Croatia; e-mail: tadesse@hgi-cgs.hr

2 – Geological-Palaeontological Department, Natural History Museum Vienna, Burgring 7, 1010 Vienna, Austria

3 – Department of Earth and Environmental Sciences, Ludwig-Maximilian-University, Richard-Wagner Str. 10, 80333 Munich, Germany

The North Croatian Basin (NCB) is an elongated rift-type basin that covers almost the entire area of northern Croatia. Two phases of basin evolution are distinguished in the NCB: the syn-rift phase, which lasted from the Ottnangian to the Middle Badenian, characterized by depositional environments that changed from continental to marine environments; and the late Badenian to the Quaternary post-rift phase, characterized by a shift from marine to continental depositional environments (Pavelić and Kovačić 2018). The formation of the sedimentary basin in the area of Papuk mountain started in the Early Miocene with terrestrial sedimentary environments that were firmly controlled by the climate (Kovačić et al. 2017 and references therein). Lithologically different Lower Miocene deposits of the NCB at Papuk, called the Poljanska unit, are represented by predominantly well-bedded dolomites, pelite layers, sandstones, tuffs, and tuffites with analcime and deposited in a salina-type lake (Šćavničar et al. 1983; Kovačić et al. 2017; Pavelić and Kovačić 2018; Pavelić et al. 2022). The Karpatian age was proposed for the salina–type deposits by Pavelić et al. (2022), based on the similarity of the deposits with cyclical alternations of dry and more humid periods of an early Miocene climate in the area and the vertical transition into the early Badenian hydrologically open lake deposition. The change from the lake deposits to the Badenian marine deposits was observed in the nearby Sokolovac section (Ćorić et al. 2009). The latter authors concluded that the NCB initial marine transgression correlates with the calcareous nannoplankton zone NN5.

We studied deposits stratigraphically underlying the Poljanska unit. The object of this study is two new sections on the south-western slopes of the Papuk Mountain, along the Sokolovac stream: the Poljanska section exposing tuffitic, continental, and brackish deposits, and the Mala section, comprising marine sediments.

At the base of the Poljanska section, tuffitic sediments bear common endemic brackish, rare marine to freshwater and terrestrial microfossils. Radiometric $^{40}Ar/^{39}Ar$ dating obtained on volcanic glass shards from this layer provided an age of 22.2 ± 1.9 Ma correlating with the earliest Early Miocene and indicating the existence of the oldest volcanic activity in the NCB pro tempore.

The succession transitions into the brackish-water lacustrine environment sediments. Within this part of the sediment succession, according to fossils, two different climatic events are recognised. The joint finding of crocodile tooth and pollen of mangrove cf. *Avicennia* in this interval implies higher temperature and may coincide with the known temperature maximum event at 16.5 Ma in the Early Miocene of the Central Paratethys (Methner et al. 2020). One interruption with lower temperatures characteristic for higher latitudes was recorded, which could be a consequence of the known cooling (Mi-2) event in the Central Paratethys set at 16.06 Ma (Sangiorgi et al. 2021; Premec Fućek in review).

The co-occurrence of limnic and marine species and the warm subtropical ferns in the uppermost part of the Poljanska section samples indicate a marine inflow into the coastal lake under the warm subtropical climate. It marks the beginning of the salina-type lake formation and the first deposits of the Poljanska unit. The remains of fish in the upper samples of the Poljanska section represent the first finding of the lowermost Miocene mugilid *Liza gaudanti* and the gobiid *Gobius* (n.) sp. in the NCB. Their findings can be explained by their migration and open connection routes between the northern part of Paratethys and NCB in the Early Miocene.

In the Mala section, the transgressive sequence is documented through the presence of marine calcareous nannoplankton, planktonic and benthic foraminifera, and ostracods. The oldest marine fauna and flora from the marine deposits of the Mala section is the latest Early Miocene in age (Karpatian; Zone NN4) and is connected with the TB 2.2.

The multiproxy study presented detailed data on the stratigraphy, chronology, mineralogy, palaeoenvironments, and palaeoclimatology of the NCB during the Early Miocene. It represents a new step in a better understanding of sedimentation and possible paleogeographic connection within Paratethys during the Early Miocene.

Acknowledgement: The authors are very grateful to Marijan Kovačić, Monika Milošević, Mirjana Miknić, Radovan Filjak, Mirko Belak and Ivo Suša for their help during the field work. Many thanks to Vlasta Premec Fućek and Morana Hernitz Kučenjak for suggestions and help with the determination of foraminiferal planktonic species, and to Marianna Kováčová for palynology. Special thanks to Tomislav Kurečić and Pavle Ferić for technical support and Janet Gabites for Ar/Ar chronology. This study was financed by the Croatian Geological Survey, the Department of Geology, and the Croatian Science Foundation under the project IP-2019-04-7042.

References:

Ćorić, S., Pavelić, D., Rögl, F., Mandic, O., Vrabac, S., Avanić, R., Jerković, L. & Vranjković, A. 2009. Revised Middle Miocene datum for initial marine flooding of North Croatian Basins (Pannonian Basin System, Central Paratethys). *Geologica Croatica*, 62, 31–43.

Kovačić, M., Tibljaš, D., Pavelić, D., Hajek-Tadesse, V., Bakrač, K., Mandic, O., Galović, I., Wacha, L., Filjak, R. & Marković, F. 2017. Early –Middle Miocene salina–type and open lake deposits. In: Kovačić, M., Wacha, L., Horvat, M. (Eds.). Field trip guidebook. 7th International Workshop, Neogene of Central and South-Eastern Europe. *Hrvatsko geološko društvo. Croatian Geological Society* Zagreb, 11-15.

Methner, K., Campani, M., Fiebig, J., Löffler, N., Kempf, O. & Mulch, A. 2020. Middle Miocene long-term continental temperature change in and out of pace with marine climate records. *Scientific Reports*, 10, 1, 7959.

Pavelić, D. & Kovačić, M. 2018. Sedimentology and stratigraphy of the Neogene rift-type North Croatian Basin (Pannonian Basin System, Croatia): a review. *Marine and Petroleum Geology*, 91, 455–469.

Pavelić, D., Kovačić, M., Tibljaš, D. Galić, I., Marković, F. & Pavičić, I. 2022. The transition from a closed to an open lake in the Pannonian Basin System (Croatia) during the Miocene Climatic Optimum: Sedimentological evidence of Early Miocene regional aridity, *Palaeogeography, Palaeoclimatology, Palaeoecology*, 586, 110786.

Premec Fućek, V., Galović, I., Mikša, G., Hernitz Kučenjak, M., Krizmanić, K., Hajek-Tadesse, V., Matošević, M., Pecimotika, G. & Zlatar, S., in review 2022. Microfossils evidence of the late Karpatian to early Badenian marine succession from Medvednica Mt., Central Paratethys. *International Journal of Earth Sciences*, https://doi.org/10.1007/s00531-022-02264-4.

Sangiorgi, F., Quaijtaal, W., Donders, T. H., Schouten, S. & Louwye, S. 2021. Middle Miocene temperature and productivity evolution at a Northeast Atlantic shelf site (IODP U1318, Porcupine Basin): Global and regional changes. *Paleoceanography and Paleoclimatology*, 36, e2020PA004059.

Šćavničar, S., Krkalo, E., Šćavničar, B., Halle, R. & Tibljaš, D. 1983. Naslage s analcimom u Poljanskoj [Analcime bearing deposits in Poljanska, Slavonia, northern Croatia – in Croatian*]. Rad JAZU*, 404, 137–169.

The Pannonian of the Vienna Basin – from Paleo-Danube Delta to post-Pannonian erosion

MATHIAS HARZHAUSER[1], MATTHIAS KRANNER[1], OLEG MANDIC[1], STJEPAN ĆORIĆ[2], ARTHUR BORZI[3], WERNER E. PILLER[3], PHILIPP STRAUSS[4], RUDOLF DELLMOUR[4] and WOLFGANG SIEDL[4]

1 – Geological-Paleontological Department, Natural History Museum Vienna, Burgring 7, 1010 Vienna, Austria; e-mail: mathias.harzhauser@nhm-wien.ac.at

2 – Geological Survey Austria, Neulinggasse 38, 1030 Vienna, Austria

3 – Institute of Earth Sciences (Geology and Paleontology), NAWI Graz Geocenter, University of Graz, Heinrichstr. 26, 8010 Graz, Austria

4 – OMV EandP GmbH, Trabrennstraße 6-8, 1020 Vienna, Austria

We present the first detailed intra-basin correlation of Upper Miocene deposits in the Austrian part of the Vienna Basin (VB) integrating the most important hydrocarbon fields. We applied a high resolution approach by separating the Pannonian stack into 20 lithostratigraphic units, which allow calculating regional differences in sedimentation rates over a time span of ~1.6 Ma. During this time span we recognize an initial phase of high lateral variability in thicknesses, reflecting the influence paleo-topography on deposition during the early Pannonian. The relief difference of about 300 m was rapidly filled by lake marls and delta lobes of the Paleo-Danube. The Paleo-Danube delta formed between c. 11.5 – 11.3 Ma as part of a 3rd order lowstand of Lake Pannon. The delta deposits are framed within two 4th order flooding surfaces, used as correlation horizons in the seismic interpretations. Morphologically, the delta is divided into a western part with a braided river delta plain and an eastern and southeastern part consisting of five distinct delta lobes, which are defined as Großengersdorf, Aderklaa, Markgrafneusiedl, Matzen and Zistersdorf lobes. Seismic architecture reveals consecutive onlaps of theses lobes, documenting that the lobes developed successively through time. The initial delta progradation was oriented in southern direction, roughly coinciding with the Aderklaa fault system. Subsequent lobes switched into eastern and northeastern directions and finally switched back into southern direction. Simultaneously, the point of origination of the lobes switched towards the northeast with the most prominent shift of 15 km occurring between the Markgrafneusiedl and the Matzen lobes. This channel migration was probably governed by a stepwise activity of the Pirawarth-Steinberg fault system. In total, the delta complex spreads over about 850 km^2. The geometry of the lobes, the steeply inclined clinoforms and the development of large beach ridge fields classify the delta as a river-dominated delta with strong influence of wave reworking, comparable to the modern Danube delta.

Subsequently, lateral variability in sediment thicknesses declined strongly around 11.0 Ma. At that point the relief was largely sealed, and subsidence became the controlling factor. Our data document a shift of high subsidence rates from the southern VB to the northern VB into three steps, initiated by increased activity of the Steinberg Fault around 10.5 – 10.4 Ma. Sedimentation rates have been declining during the early Pannonian but reveal a strong pulse in subsidence during the middle Pannonian. The still high sedimentation rates during the late Pannonian indicate persisting extensional tectonics in the VB throughout the Late Miocene and contradict the prevailing tectonic model of a compressional regime. The lack of uppermost Pannonian deposits in most wells documents a post-Miocene erosion of Pannonian strata of 200 – 400 m in large parts of the VB.

Strontium Isotope Stratigraphy in epicontinental basins – possibilities and restrictions – a case study from the Middle Miocene of the Central Paratethys

KATARÍNA HOLCOVÁ[1], FILIP SCHEINER[1,2], LUKÁŠ ACKERMAN[1,2], RASTISLAV MILOVSKÝ[3], NATÁLIA HUDÁČKOVÁ[4], MIHOVIL BRLEK[5] and DANUTA PERYT[6]

1 – Institute of Geology and Palaeontology, Charles University, Albertov 6, 128 43 Praha 2, Czech Republic; e-mail: holcova@natur.cuni.cz

2 – Institute of Geology of the Czech Academy of Sciences, Rozvojová 269, 165 00 Praha 6 Lysolaje, Czech Republic

3 – Earth Science Institute, Slovak Academy of Sciences, Ďumbierska 1, 974 01 Banská Bystrica, Slovak Republic

4 - Department of Geology and Paleontology, Faculty of Natural Sciences, Comenius University in Bratislava, Mlynská dolina, Ilkovičova 6, 842 15 Bratislava, Slovak Republic

5 – Department of Geology, Croatian Geological Survey, Sachsova 2, 10000, Zagreb, Croatia

6 – Polish Academy of Sciences, Institute of Paleobiology, Twarda 51/55, 00-818 Warszawa, Poland

To correlate local stratigraphic schemes from epicontinental basins, which are characterized by periodical connections with the surrounding oceanic realms and by varying paleoenvironmental conditions, with the standard chronostratigraphy is a challenging problem. It is mainly because employed stratigraphic methods show a degree of uncertainty when applied in these environments.

A reliability of chemostratigraphy represented here by Strontium Isotope Stratigraphy (SIS) was tested for the epicontinental Central Paratethys using a large set of $^{87}Sr/^{86}Sr$ data (130) from the uppermost Burdigalian to Serravallian. During this interval, a significant marine connection between the Central Paratethys and the Mediterranean that was characterised by a prevailing down welling circulation regime was established. Then, the gateway was gradually closed in the end of this interval (Kováč et al. 2017).

Foraminifera, otoliths and molluscs shells were used for $^{87}Sr/^{86}Sr$ analyses from the selected sections, where there were multiproxy paleoenvironmental data available. Further, SIS ages estimated from the LOESS look-up table for conversion of $^{87}Sr/^{86}Sr$ to age (McArthur et al. 2020) were compared with the ages obtained by microbiostratigraphy, and where possible with radiometric ages. Besides Sr-values from the world ocean, we confronted the Central Paratethys $^{87}Sr/^{86}Sr$ with the signal from the Mediterranean Sea.

Our results suggest that there is not possible to construct a unified local Central Paratethys Sr-isotope curve. An agreement with the global Sr-curve was recorded mainly for surficial waters in the central part of the studied basins, but the signal of bottom and surficial waters can substantially differ. In the marginal parts of the studied basins, the negative Sr-isotope variation was observed in the case of coastal area surrounded by karst, whereas the observed positive variations could indicate areas with a notable fresh-water inflow.

Sections that were characterised by a common presence of volcanic material showed no clear trend and a variability in Sr-isotope signal being both positive and negative.

Based on our results, SIS in epicontinental basins gives valuable supportive age information, but a detailed application requires using an integrate-stratigraphic approach.

Acknowledgement: This work has been supported by the Czech Science Foundation project No. GA20-05872S while institutional support was provided by research programme RVO 67985831 (Institute of Geology of the Czech Academy of Sciences), by the Centre for Geosphere Dynamics, UNCE/SCI/006 and COOPERATIO (Charles University), Slovak Research and Development Agency (APVV-16-0121 and APVV-20-0079) and by the National Science Centre, Poland, grant No. UMO-2017/27/B/ST10/01129.

References:

Kováč, M., Hudáčková, N., Halásová, E., Kováčová, M., Holcová, K., Oszczypko-Clowes, M. & Jamrich, M. 2017. The Central Paratethys palaeoceanography: a water circulation model based on microfossil proxies, climate, and changes of depositional environment. *Acta Geologica Slovaca*, 9, 2, 75-114.

McArthur, J.M., Howarth, R.J., Shields, G.A. & Zhou Y. 2020. Strontium isotope stratigraphy. In: Gradstein, F.M., Ogg. J.G., Schmitz, M.D. and Ogg, G.M. *A Geologic Time Scale*, Elsevier B.V., Vol 1 of 2, pp. 211–238.

Brezno-Za dolinou – occurrence of Fe-Cu-Sb-As mineralization and its relationship to the Alpine tectonics

EVA HOPPANOVÁ, VIERA ŠIMONOVÁ,
ŠTEFAN FERENC and RICHARD KOPÁČIK

Department of Geography and Geology, Faculty of Natural Sciences, Matej Bel University, Tajovského 40, 974 01 Banská Bystrica, Slovak Republic; e-mail: eva.hoppanova@umb.sk

Number of small historical deposits and mineralogical occurrences of the Fe, Cu, Ag and Sb ores is situated in the area of the northern part of Vepor Belt. The most important of them are located especially in the vicinity of Špania Dolina, Poniky, Ľubietová and Čierny Balog villages. Many less known occurrences of Cu, Fe, Pb, Zn, Ag, As, Au mineralization also are there: Šumiac, Bacúch, Pohronská Polhora, Polomka, Ľubietová, Harmanec etc. (Slavkay and Petro 1993; Slavkay et al. 2004).

Such occurrences also include unknown occurrence named Brezno-Za dolinou (conformity with Horal 1955), approximately 5 km NNE from the Brezno district town. The submitted contribution is devoted to a brief geological description of this interesting, so far unstudied ore occurrence.

The mineralogical occurence of the metasomatic Fe-Cu-Sb-As mineralization is located in the tectonic zone (brecciated Mesozoic carbonates), respectively in the Alpine thrust line of the Hronic Unit (Mesozoic Ramsau dolomites, limestones, dolomites; Bystrický 1972) on the Mesozoic rocks (shales, carbonates) of the Ľubietová zone of the Northern Veporicum Unit (*sensu* Zoubek 1936). The main minerals are pyrite and minerals of the tetrahedrite group, accompanied by chalcostibite, sphalerite, chalcopyrite, marcasite, stibnite, luzonite, cubanite, berthierite, bournonite galena, Pb-Sb sulphosalts, dolomite and calcite. Supergene alteration is represents by the brochantite, goethite, anglesite and covellite. The oldest element of the crystalline complex of Veporic Unit are medium and higher grade metamorphites (garnet-muscovite-biotite paragneiss, gneisses and mica schists). The cover sequences of the crystalline complex are formed here by Triassic rocks (quartz sandstones, arkoses, conglomerates, slates dolomites, rauwackes, breccias) and Jurrasic rocks (mainly marls and shale limestones). Quaternary sediments are represented by slope silty gravels (resedimented) and fluvial gravels (Vozár et al. 1998).

The field investigation has been also focused on tectonic deformation of studied area. The computation of stresses and the separation of the joints into homogenous groups were made using the program Win_Tensor.

Palaeostress analysis revealed the existence of four different Alpine palaeostress fields. The oldest deformation phase is characterized by compression in the WNW–ESE direction that was generated during the compressive tectonic regime. This event was accompanied by the formation of the joints trending in the approximately W–E direction. The second deformation stage represents joints generated by a transpressional regime with the NNW–SSE maximum horizontal stress axis SHmax. The structures are oriented to NNW–SSE. The next deformation phase is characterized by the change of the transpressional tectonic regime to compressional and by rotation of the compression stress axis from NNW–SSE to N–S up to NNE–SSW direction. During this time, N–S joints were activated. The latest deformation phase is characterized by extensional tectonic regime with extensional component of the stress field oriented to NNW-SSE direction. The joints generated in this phase (ENE–WSW direction) are a harbinger of the change of compressional tectonic regime to extensional one.

Acknowledgement: This work was supported by the Slovak Research and Development Agency under the contracts KEGA 033UMB-4/2021, VEGA 1/0563/22 and APVV-19-0065.

References:

Bystrický, J. 1972. Faziesverteilung der mittleren und oberen Trias in den Westkarpaten. *Mittel Gesellschaft Geologie – u. Bergb.-Studenten* (Innsbruck) 21, 289–310.

Horal, K. A. 1955. Rukopisné poznámky. Manuskript, 164.

Slavkay, M., Beňka, J., Bezák V., Gargulák, M., Hraško, Ľ., Kováčik, M., Petro, M., Vozárová, A., Hruškovič, S., Knéls, J., Knélsová, A., Kusein, M., Maťová, V. & Tulis, J. 2004. *Ložiská nerastných surovín Slovenského Rudohoria 2. GÚDŠ* Bratislava. 286.

Slavkay, M. & Petro, M. 1993. Metalogenéza a rudné formácie veporika. *Mineralia Slovaca* 25, 313–317.

Vozár, J., Káčer, Š. (eds.), Bezák, V., Elečko, M., Gross, P., Konečný, V., Lexa, J., Mello, J., Polák, M., Potfaj, M., Rakús, M., Vass, D. & Vozárová, A. 1998. *Geologická mapa Slovenskej republiky* 1 : 1 000 000. Bratislava, MŽP SR – GS SR.

Zoubek, V. 1936. Poznámky o krystaliniku Západních Karpat. *Věstník Státního Geologického Ústavu ČSR* 12, 207–239.

Mineralogical and geochemical proxies of the Lower Miocene sediments of Mtn. Papuk – Poljanska and Mala sections (Northern Croatia)

MARIJA HORVAT[1], LARA WACHA[1], ANITA GRIZELJ[1], VALENTINA HAJEK TADESSE[1], INES GALOVIĆ[1], KORALJKA BAKRAČ[1], OLEG MANDIĆ[2] and BETTINA REICHENBACHER[3]

1 - Croatian Geological Survey, Sachsova 2, 10 000 Zagreb, Croatia; e-mail: mhorvat@hgi-cgs.hr

2 - Geological-Palaeontological Department, Natural History Museum Vienna, Burgring 7, 1010 Wien, Austria

3 - Department of Earth and Environmental Sciences, Ludwig-Maximilian-University, Richard-Wagner Str. 10, 80333 Munich, Germany

The Poljanska and Mala sections are located on the south-western slopes of Mtn. Papuk in the northern part of Croatia, close to the active Poljanska quarry. The Poljanska succession starts with light grey tuffitic sediments. Above the tuffitic sediment, a thin grey siltstone layer and a brown medium-grained limonitized silty sand layer with seepage cracks are exposed. The silty sand continues into dark grey layered siltstone rich in plant remains and mollusc shells. Above the fossiliferous siltstone, a lens of light grey medium-grained silty sand appears, followed by grey horizontally layered fossiliferous silt intercalated with a few cm thick coal lens. The subsequent sedimentation was represented by the exchange of clayey sandy silt and silty sand. The uppermost part of the section is dominated by horizontally laminated grey siltstones and thin bentonite and clayey, silty sand interlayers. Mala section lithotype is determined as gravelly silty sand.

The modal composition of the tuffitic sediment and silty sand samples was performed to determine the provenance of the material. All samples contain quartz and feldspars as a light mineral fraction (LMF). Only the tuffitic sediment and the silty sand layer above it additionally contain volcanic glass particles in the LMF. Gravelly silty sand of the Mala section and silty sand from the middle and upper part of the Poljanska section contains muscovite and lithic fragments. Among the transparent heavy minerals (THM), garnet and pyroxene (mostly orthopyroxene) grains are predominant in the tuffitic sediment. In contrast, gravelly silty sand and silty sand above tuffitic sediment predominantly contain garnet. In the upper part of the Poljanska section, silty sands contain pyroxene as prevalent. The tuffitic sediment contains 45% of fresh volcanic glass shards in the LMF. The XRPD analyses also proved volcanic glass by the broadening diffraction maximum at 20 – 30 °2θ, originating from an amorphous compound. The multi-purpose SEM images of glass shards show their angular shape and abundant pipe vesicles and bubble walls. The mineralogical composition of gravelly silty sand, tuffitic sediment, siltstone, and silty sand samples were also analysed by XRPD. Among clay minerals, the main component in all samples is the dioctahedral smectite, which corresponds to beidellite. Only the uppermost part of the section contains zeolite minerals from the clinoptilolite/heulandite group. The bulk rock chemistry of tuffitic sediment and silty sand samples was conducted. In the studied samples, SiO_2/Al_2O_3 ratio for tuffitic sediment and the following silty sand layer sample is slightly higher, 4.84 and 4.25, respectively, than in other samples (3.07 – 2.61). This is consistent with the analysis of the modal composition of the same sediments because these two samples contain volcanic glass shards. The K_2O/Al_2O_3 ratio is used as an indicator of the source composition of sediments. The studied samples, excluding one sample from the upper part of the section, have the same K_2O/Al_2O_3 ratio less or equal to 0.5, indicating feldspar-rich source rocks. The degree of chemical weathering of the source rocks was constrained by calculating the chemical index of alteration (CIA= $[Al_2O_3/(Al_2O_3+CaO^*+Na_2O+K_2O)]$x100. The CIA index, between 65 and 76, indicates weak to intermediate intensity of chemical weathering in the source area. The samples of the Poljanska and Mala sections are plotted near the (CaO*+Na2O)–Al2O3) line and follow the trend of the average tonalite and gabbro weathering (Nesbitt and Young 1984). Tuffitic sediment and one silty sand sample from the upper part of the section show a more intermediate igneous provenance, while other samples show mafic igneous provenance source rocks. The $^{40}Ar/^{39}Ar$ Ar dating method was applied on separated volcanic glass particles from the tuffitic sediment. The inverse isochron age of the volcanic glass shards of 22.2 ± 1.9 Ma is considered to be the best estimate $^{40}Ar/^{39}Ar$ age.

Mineralogical analyses revealed that the deposits are of a hybrid origin, both pyroclastic and terrigenous. The pyroclastic material is mainly slightly altered into smectite and clinoptilolite heulandite type of zeolites (the uppermost part of the Poljanska section). The occurrence of clinoptilolite/heulandite-type zeolites was probably caused by a gradual increase in aridity and salinity. Bulk rock chemical analysis suggests an intermediate to prevailing mafic chemical composition source rock affinity. The new age data presented within this study does not correlate to the rhyolite volcanic activity in the North Croatian Basin (NCB) as we expected but very likely implies the existence of an even older volcanic activity in the NCB, which may have provided material for the formation of the studied rocks.

Acknowledgement: The authors are very grateful to Marijan Kovačić, Monika Milošević, Mirjana Miknić, Radovan Filjak, Mirko Belak and Ivo Suša, for their help during the fieldwork. Special thanks to Janet Gabites for Ar/Ar chronology. This study was financed by the Department of Geology of the Croatian Geological Survey.

References:

Nesbitt, H.W. & Young, G.M. 1984. Prediction of some weathering trends of plutonic and volcanic rocks based on thermodynamic and kinetic considerations. *Geochimica et Cosmochimica Acta*, 48, 1523–1534.

Mineral selectiveness in agglutinated foraminifera from the Middle Miocene Hámor site (Novohrad-Nógrád Basin)

NATÁLIA HUDÁČKOVÁ[1], KATARÍNA ŠARINOVÁ[2], MICHAL JAMRICH[1] and ANDREJ RUMAN[1]

1 – Department of geology and paleontology, Faculty of Natural Sciences, Comenius University in Bratislava, Mlynská dolina, Ilkovičova 6, 842 15 Bratislava, Slovakia; e-mail: natalia.hudackova@uniba.sk

2 – Department of mineralogy, petrology and economic geology, Faculty of Natural Sciences, Comenius University in Bratislava, Mlynská dolina, Ilkovičova 6, 842 15, Bratislava, Slovakia

Respected material for this study comes from Lower Badenian deposits of the originated from of the Middle Miocene Hámor site (Langhian; Vinica Formation; Novohrad-Nógrad Basin; Central Paratethys; Čechovič and Seneš, 1950; Vass et al., 1979; Kováč et al., 2017, 2018; Hudáčková et al., 2020).

Specimen and species rich deposits of this site yielded diversified associations both micro and macrofossils. Association of NN5 Zone were identified in the studied sample contains *Coccolithus miopelagicus*, *Discoaster musicus*, *Helicosphaera waltrans*, *H. walbersdorfensis*, *Sphenolithus heteromorphus*. Absence of *Helicosphaera ampliaperta* supports this age assignment. Mentioned taxa prefer warm water paleoenvironments with lower nutrient input. Such assumption supports the presence of other paleoecological indicators such as *Calcidiscus leptoporus*, *C. tropicus*, *Umbilicosphaera jafari* and *U. rotula* reflecting the strong preference for warmer and/or lower nutrient concentrations as well. Diversified foraminiferal assemblages are prevailed by benthic taxa, e.g., *Asterigerina* sp., *Hanzawaia boueana*, *Cibicidoides lobatulus*, high spiral *Ammonia parkinsoniana*, *Textularia* sp. Hudáčková et al., 2020). Planktonic forms are dominated by *Globigerinoides*/*Trilobatus* group with abundant indicative *Orbulina suturalis*.

Although the agglutination patterns (size and nature of the cemented particles) are amongst the taxonomic attributes of the agglutinated foraminifera, its possible ad hoc formation should still be considered. Moreover, such shell development can reflect environmental heterogeneities and factors affecting the given area.

The aim of this study was to investigate implications of unusual mineral content of tests in *Pseudogaudryina* sp. (canaliculate agglutinated foraminifera), specifically sudden increase in inosilicate portion (number and size) in overall wall-grain content, possibly indicating nearby volcanic activity. Pyroxene grains, if present, are normally evenly distributed between the wall material of agglutinated foraminifera. With respect to the presence of this mineral content compared to normal, specimens from the studied locality can be divided into three clusters of general appearance: i) no difference, ii) high proportion, and iii) sudden appearance within a single test. Noteworthy to mention is that however some specimens with pyroxene grains builted-in to walls were also identified amongst the miliolid forms some genera of agglutinated foraminifera remain without any change in amount of this mineral.

The minerals that were enclosed in the foraminifera are identical to those found in the sands. The presence of glass shards, and the dominance of pyroxenes (enstatite, augite), plagioclase (An 48-68), amphiboles (pargasite, hastingsite, horblende), ilmenite + apatite document the significant influence of andesite volcanic activity. The non-volcanic admixture documents the presence of quartz, albite, K-feldspar and small foraminifers, which are also present in the shells.

If taken into consideration that the pyroxene grains remain non-degraded only for limited time in the environment and after a certain period become unavailable due to chemical and physical degradation. Whether builted-in pyroxene grains have a greater preservation potential to remain longer time in the environment is disputed since it commonly occurred in the ambient sediment. In general, it should apply that if they are built into the wall, they get an organic lining and thus also protection against pore water and corrosion respectively. Another attribute affecting physical nature of the sediment particle is an increase in size as the foraminiferal test plays as a single “grain”.

Since the Middle Miocene is the epoch of significant rearrangement and changes in the Central Paratethyan both marine and terrestrial environments, timing of particular striking short-term, local events (e.g., volcanism) can be crucial for further interpretation in regional context.

Acknowledgement: The study was supported by the Slovak Research and Development Agency (SRDA/APVV) under contracts No. APVV-16-0121, APVV-20-0079, APVV-20-0120, and by the Scientific Grant Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic and the Slovak Academy of Sciences (VEGA) under the contracts VEGA2/0169/19 and VEGA-2/0013/20.

References:

Čechovič, V. & Seneš, J. 1950. Tortonian of the Modrý Kameň area. *Geologický Sborník, Slovenská Akadémia Vied a Umení,* 1, 2–4, 130–166. (In Slovak with Russian and French summary).

Hudáčková, N., Holcová, K., Halásová, K., Kováčová, M., Doláková, N., Trubač, J., Rybár, S., Ruman, A., Stárek, D., Šujan, M., Jamrich, M. & Kováč, M. 2020. The Pannonian Basin System northern margin paleogeography, climate, and depositional environments in the time range during MMCT (Central Paratethys, Novohrad-Nógrád Basin, Slovakia). *Palaeontologia Electronica,* 23, 3, a50. https://doi.org/10.26879/1067

Kováč, M., Hudáčková, N., Halásová, E., Kováčová, M., Holcová, K., Oszczypko-Clowes, M., Báldi, K., Less, Gy., Nagymarosy, A., Ruman, A., Klučiar, T. & Jamrich, M. 2017. The Central Paratethys palaeoceanography: a water circulation model based on microfossil proxies, climate, and changes of depositional environment. *Acta Geologica Slovaca,* 9, 2, 75–114.

Kováč, M., Halásová, E., Hudáčková, N., Holcová, K., Hyžný, M., Jamrich, M. & Ruman, A. 2018. Towards better correlation of the Central Paratethys regional time scale with the standard geological time scale of the Miocene Epoch. *Geologica Carpathica,* 69, 3, 283–300.

Vass, D., Konečný, V. & Šefara J. (Eds.) 1979. *Geology of Ipeľská kotlina (depression) and Krupinská planina Mts.* Geologický Ústav Dionýza Štúra, Bratislava. 277 pp. (In Slovak with English summary).

New fossil association of the Badenian open coast tidal flats from the Novohrad-Nógrad Basin (Slovakia)

MATÚŠ HYŽNÝ[1], SAMUEL RYBÁR[1], NATÁLIA HUDÁČKOVÁ[1], ANDREJ RUMAN[1], MICHAL JAMRICH[1], KATARÍNA HOLCOVÁ[2], EVA HALÁSOVÁ[1] and KAMIL ZÁGORŠEK[3]

1 – Department of Geology and Palaeontology, Faculty of Natural Sciences, Comenius University, Ilkovičova 6, 84215 Bratislava, Slovak Republic; e-mail: matus.hyzny@uniba.sk

2 – Institute of Geology and Palaeontology, Charles University, Albertov 6, 128 43 Prague, Czech Republic

3 – Department of Geography, Technical University of Liberec, Univerzitní náměstí 1402/2, 461 17 Liberec, Czech Republic

The Miocene sedimentary infill of the Pannonian Basin System represents various palaeoenvironments reflecting the complex geodynamic evolution of the former Paratethys Sea and Lake Pannon (Rögl 1998; Popov et al. 2004; Magyar et al. 2013; Kováč et al. 2017). In the Novohrad-Nógrad Basin, the Middle Miocene sediments are exposed in several outcrops (Vass et al. 1979; Vass 2002; Hudáčková et al. 2020). Recent fieldworks at one of them, the Hámor section, yielded a rich fossil association.

In the studied section, located NE from the Hámor village (coordinates 48°12'51.95"N, 19°31'35.79"E, 190 m.a.s.l.), the lower Badenian (Langhian) strata of the Príbelce Member (Vinica Formation) are exposed. Two facies alternate rhythmically within the section: coarse, occasionally pebbly sandstones and horizontally bedded clast-supported gravels with a sandy matrix. The fossil association was documented from the latter lithofacies. Based on the nannoplankton assemblage with *Sphenolithus heteromorphus* and *Helicosphaera waltrans*, the studied section can be correlated with the MNN5a Subzone *sensu* Fornaciari et al. (1996) and NN5a Subzone *sensu* Andrejeva-Grigorovič et al. (2001). The diverse foraminiferal assemblage is dominated by benthic species (*Biasterigerina planorbis*, *Cibicides boueanus*, *Lobatula lobatula*, *Ammonia parkinsoniana*, *Textularia* sp. div.). Macrofauna includes corals, molluscs (*Anomia ephippium*, Ostreidae indet., *Pecten subarcuatus styriacus*, *Oopecten solarium*, *Costellamussiopecten cristatus badense*, *Crassadoma multistriata*), bryozoans (*Myriapora truncata*, *Schizoporella teragona*, *Adeonellopsois* sp., *Crisia* cf. *C. eburnea*, *Crisia* cf. *C. haueri*, *Cellaria fistulosa*, *Scrupocellaria elliptica*, *Retepora* sp., *Margaretta* sp., *Pleuronea pertusa*, *Mecynoecia* sp.), barnacles, decapod crustaceans (*Eucalliaxiopsis pseudorakosensis*, *Neocallichirus* sp., *Petrochirus priscus*, *Pagurus rakosensis*, *Dardanus* sp., *Szaboa inermis*, *Calappa* sp., *Liocarcinus* sp.), echinoderms, and sharks. Trace fossils include *Ophiomorpha*-like burrow remains belonging to ghost shrimps (*E. pseudorakosensis*, *Neocallichirus* sp.).

Based on the sedimentological analysis, the palaeoenvironment of the studied strata is interpreted as open-coast tidal flats. The palaeoenvironment of the Príbelce Member as representing tidal settings was already interpreted in the previous sedimentological analyses from the area (Čechovič and Seneš 1950; Vass et al. 1979; Vass 2002). Tidal channels were also reported by Vass et al. (1979) from the outcrops in the close vicinity; however, they were not identified at the Hámor locality previously. Although Vass (1977) claimed that the sand originated in the littoral environment under tidal control and later changed into a delta environment, the fauna documented herein, also consisting of some stenohaline elements (e.g., echinoids and pectinids), point to a fully marine environment, which is in agreement with the results of Hudáčková et al. (2020) studying localities in a wider area.

Acknowledgement: The research was supported by Slovak Research and Development Agency (APVV-16-0121 and APVV-20-0079) and Funding Agency of Ministry of Education, Science, Research and Sport of the Slovak Republic (VEGA 2/0013/20 and VEGA-1/0526/21).

References:

Andrejeva-Grigorovič, A.S., Kováč, M., Halásová, E. & Hudáčková, N. 2001. Litho- and biostratigraphy of the Lower and Middle Miocene sediments of the Vienna basin (NE part) on the basis of calcareous nannoplankton and foraminifers. *Scripta Facultatis Scientiarum Naturalium Universitatis Masarykianae Brunensis Geologie,* 30, 23–27.

Čechovič, V. & Seneš, J. 1950. Tortonian of the Modrý Kameň area and vicinity. *Geologický Sborník,* 2, 4, 130–166 (in Slovak).

Fornaciari, E., Si Stefano, A., Rio, D. & Negri, A. 1996. Middle Miocene quantitative calcareous nannofossil biostratigraphy in the Mediterranean region. *Micropaleontology,* 42, 1, 37–63.

Hudáčková, N., Holcová, K., Halásová, K., Kováčová, M., Doláková, N., Trubač, J., Rybár, S., Ruman, A., Stárek, D., Šujan, M., Jamrich, M. & Kováč, M. 2020. The Pannonian Basin System northern margin paleogeography, climate, and depositional environments in the time range during MMCT (Central Paratethys, Novohrad-Nógrád Basin, Slovakia). *Palaeontologia Electronica*, 23, 3, a50.

Kováč, M., Márton, E., Oszcypko, N., Vojtko, R., Hók, J., Králiková, S., Plašienka, D., Klučiar, T. & Hudáčková, N. 2017. Neogene palaeogeography and basin evolution of the Western Carpathians, Northern Pannonian domain and adjoining areas. *Global and Planetary Change,* 155, 13–154.

Magyar, I., Radivojenić, D., Sztanó, O., Synak, R., Ujszászi, K. & Pócsik, M. 2013. Progradation of the paleo-Danube shelf margin across the Pannonian Basin during the Late Miocene and Early Pliocene. *Global and Planetary Change,* 103, 168–173.

Popov, S.V., Rögl, F., Rozanov, A.Y., Steininger, F.F., Shcherba, I.G. & Kováč, M. (ed.) 2004. Lithological-Paleogeographic maps of Paratethys. 10 maps. Late Eocene to Pliocene. *Courier Forschungsinstitut Senckenberg,* 250, 1–46.

Where are the roots of the Western Carpathians? – Provenance and detrital zircon study of the Tatric Unit basement

MILAN KOHÚT

*Earth Science Institute, Slovak Academy of Sciences, Dúbravská cesta 9,
840 05 Bratislava, Slovak Republic; e-mail: milan.kohut@savba.sk*

The Western Carpathians are the northernmost, E–W trending branch of this Alpine belt, linked to the Eastern Alps in the west and to the Eastern Carpathians in the east. The correlation of the Variscan and pre-Variscan basement rocks of the Western Carpathians with the pre-Mesozoic basement areas of the European Variscides and Alpine orogenic belts is still questionable due to a lack of precise age and compositional data of the metamorphic units, and/or detrital zircon study.

The Western Carpathians crystalline basement (WCCB) recorded common indications of the Cadomian/Avalonian basement precursors. The pre-Mesozoic basement of the Tatric Unit was studied with respect to its lithological, structural, metamorphic and age characteristics. The obtained data proves that this basement is made of two different rock complexes – the older Lower Étage (Cambrian to Silurian) showing high-grade metamorphic evolution, and the Upper Étage (Upper Silurian to Devonian) presenting low-grade metamorphism and younger stage of development.

The Lower Étage is composed by a leptynite-amphibolite complex (LAC) with remnants of retrogressed eclogites and metaultramafites, tonalitic gneisses, sheared Cambrian-Ordovician felsic magmatites – now orthogneisses, and these metaigneous rocks are intercalated with metamorphosed psammites/pelites (gneisses) with rare carbonatic (calc-silicates) lenses, and scarce black schists. The metamorphic conditions of this complex are usually characterized by 650 – 800 MPa and 600 – 780°C, sometimes with characteristic widespread migmatization/ granitization, whereas P–T reached up to 1.2 – 2.5 GPa and 700 – 750°C in the HP eclogite remnants. The Upper Étage is the Upper Silurian – Devonian age, and typically comprises volcano-sedimentary sequences composed of metagreywackes, phyllites, metabasites (epidote-actinolite amphibolites), black shales, lenses of calc-silicates, Fe + Pb–Zn Lahn-Dill mineralization, and scarce apatite-rich rocks. Their low grade metamorphism reached a greenschist facies only (below 350 MPa and 650 °C), and weak intrusive migmatitic zones are merely observed. Mutual relationship of the Lower and Upper structural étages is commonly in normal position in respect of the Variscan tectonics, albeit overturned stacking is documented as well. Noteworthy, the LAC metabasic rocks of the Lower Étage have low positive εNd values and high Nd model ages what indicate origin from the recycled SCLM, whereas the Upper Étage mafic (gabbroic) members show an affinity to juvenile mantle products with high positive εNd values and low Nd model ages, identical to their U–Pb zircon magmatic ages. Most of the Lower Étage rocks show high-grade metamorphism, and have their origins in the Rheic Ocean. However, all rocks of the Upper Étage recorded only low-grade metamorphism, and because never experienced high-grade overprint it is evident that the Upper Étage volcanic-sedimentary rocks were not significantly subducted, and were deposited in a different realm like was the Rheno-Hercynian basin.

Representative U–Th–Pb detrital zircon data from metamorphosed siliciclastics of the Tatric Unit WCCB indicate a general dominance of Neoproterozoic – mainly Ediacaran source rocks. The latter are interpreted to have been located at the Cadomian arc supplied mostly from the Saharan Metacraton (Fig. 1). Combined with less frequent Archean and Paleoproterozoic zircon populations a common Gondwanan provenance is proposed. However, some samples contain Mesoproterozoic detrital zircons populations that are typical for the Avalonian microcontinent. The studied metamorphic rocks are interpreted to originate from the Rheic Ocean and also partly from the Rheno-Hercynian basin. Indeed, significant differences in the metamorphic evolution of both metamorphic rock assemblages suggest their recent juxtaposition and or their thrusting during the Late Devonian to Carboniferous (Visean) Variscan subduction/collision processes. The Variscan amalgamation of the Western Carpathians basement was a consequence of subduction of the Rheic Ocean under Galatian Superterrane, and final collision with marginal Rheno-Hercynian zone. For more details see Kohút et al. (2022).

Acknowledgement: Support from Slovak Research and Development Agency: Grant APVV-0549-07, APVV-18-0107 and VEGA 2/0056/20, VEGA 2/0075/20 is greatly appreciated.

References:

Kohút, M., Linnemann, U., Hofmann, M., Gärtner, A. & Zieger, J. 2022. Provenance and detrital zircon study of the Tatric Unit basement (Western Carpathians, Slovakia). *International Journal of Earth Sciences*, 111, 2149–2168.

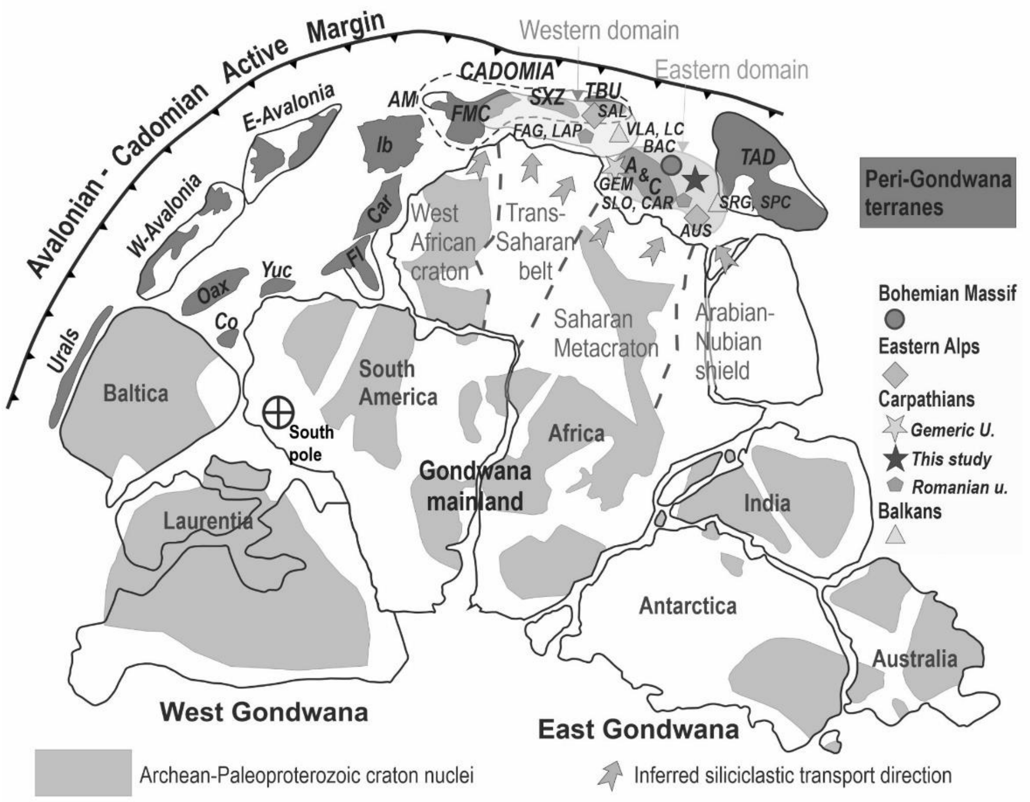


Figure 1: The palaeogeographic map showing the presumed position of terranes along the northern Gondwana margin during the late Neoproterozoic to early Cambrian times with location samples from the Tatric Unit. For more details see Kohút et al. (2022).

The Western Carpathians back-axis basins sedimentary record: new geochronological, biostratigraphical and multiproxy data, results of sedimentology, structural geology and geophysics

MICHAL KOVÁČ[1], EVA HALÁSOVÁ[1], JOZEF HÓK[1], NATÁLIA HUDÁČKOVÁ[1], MATÚŠ HYŽNÝ[1], TOMÁŠ KLUČIAR[1], MICHAL JAMRICH[1], PETER JONIAK[1], MARIANNA KOVÁČOVÁ[1], SILVIA OZDÍNOVÁ[2], PETRONELA NOVÁKOVÁ[1], ANDREJ RUMAN[1], SAMUEL RYBÁR[1], MARTIN SABOL[1], JÁN SCHLÖGL[1], ĽUBOMÍR SLIVA[1], JÁN SOTÁK[2], LENKA ŠAMAJOVÁ[1], KATARÍNA ŠARINOVÁ[3], MICHAL ŠUJAN[1], VIKTÓRIA ŠUBOVÁ[1], ADAM TOMAŠOVÝCH[2], TOMÁŠ VLČEK[1], RASTISLAV VOJTKO[1]
and colleagues from
AUSTRIA*, BULGARIA*, CROATIA*, CZECH REPUBLIC*, HUNGARIA*, THE NETHERLANDS*, POLAND* and ROMANIA*

1 – Department of geology and paleontology, Faculty of Natural Sciences, Comenius University in Bratislava, Mlynská dolina, Ilkovičova 6, 842 15 Bratislava, Slovak Republic; e-mail: kovacm@uniba.sk

2 – Earth Science Institute of the SAS, Dúbravská cesta 9, 840 05 Bratislava, Slovak Republic

3 – Department of mineralogy, petrology and economic geology, Faculty of Natural Sciences, Comenius University in Bratislava, Mlynská dolina, Ilkovičova 6, 842 15, Bratislava, Slovak Republic

** – Katalin Báldi, Stjepan Ćorić, László Csontos, Nela Doláková, Sorin Filipescu, László Fodor, Mathias Harzhauser, Katarína Holcová, Dimiter Ivanov, Marijan Kovačić, Wout Krijgsman, Imre Magyar, Oleg Mandic, Emò Márton, Mariana Marunteanu, Nestor Oszczypko, Marta Oszczypko-Clowes, Davor Pavelić, Ivica Pavičić, Karin Sant, Krisztina Sebe, Orsolya Sztanó*

More than two-decade-long investigation at projects financed mainly by the Research and Development Agency of Slovak Republic, as well as the bilateral cooperation with colleagues from abroad brought remarkable new results of basin analysis of the Western Carpathian late Cenozoic sedimentary record and so enabled progress in:

Geochronology - age determination of lithostratigraphic units. Accurate dating and modern biostratigraphy helped us to adjust and correlate several stage boundaries in the regional, as well as standard time scale stages (e.g., Pálfy et al. 2007; Kocis et al. 2009; Mandic et al. 2012; Rybár et al. 2015, 2019; Šujan et al. 2016; Sant et al. 2020; Brlek et al. 2020; Hudáčková et al. 2020; Csibri et al. 2018; Ruman et al. 2021; Šarinová et al. 2021a,b; Lukács et al. 2022; Kopecká et al. 2022). Determining the exact age of sedimentary sequences often led to a change in their local lithostratigraphic classification (e.g., Vass 2002) to another regional, or standard stage, e.g., to shift the Salgótarján Formation from the Ottnangian to Karpatian regional stage.

Sequence stratigraphy. Prominent transgressions and regressions reflected in sedimentary record of individual basins allowed correlation between various areas of the Central Paratethys (CP) with common geodynamic development, as well as it pointed out to its connections with Mediterranean and Eastern Paratethys (e.g., Hohenegger et al. 2009, 2014; Popov et al. 2010; Kováč et al. 2017a; Püspöki et al. 2017; Ivančič et al. 2018; Garefalakis and Schlunegger 2019; Hofmayer et al. 2019; Šujan et al. 2021a; Rybár et al. 2019, 2021; Hudáčková et al. 2020; Šarinová et al. 2021b; Ruman et al. 2021; Vlček et al. 2022; Šubová et al. 2022).

Sedimentology. Emerging phenomena in sedimentary fill (facies) of various basins linked to a certain depositional environment or climatic conditions (volcanic products, evaporates, carbonates, tidal deposits, coal seams) was possible to correlate between CP basins, while linking it to certain age (e.g., Krézsek and Bally 2006; Hohenegger et al. 2009, 2014; Sóron 2011; Oszczypko et al. 2014, 2016; Nováková et al. 2020; Joniak et al. 2020; Šarinová et al. 2020; Sztanó et al. 2016; Vlček et al. 2020; Csibri et al. 2022; Kopecká et al. 2022).

Structural geology and geophysical methods helped to understand geodynamic models and so adequately explaining some significant (so far unanswered) changes in the paleogeography of CP during the late Cenozoic (e.g., Balla 1984; Ratschbacher et al. 1991a,b; Tari 1993; Csontos 1992; Fodor et al. 1998, Csontos et al. 2002, Rögl 1998; Popov et al. 2004; Márton et al. 2007; Harzhauser and Piller 2007; Schmid et al. 2008, Ustaszewski et al. 2008; Mandic et al. 2012; Rybár et al. 2015, Klučiar et al. 2016; Hók et al. 2016; Kováč et al. 2016, 2017b, 2018b, 2018c; Sant et al. 2017, Šujan et al. 2021b).

Palaeogeographical models and reconstructions, based on new data explain spatiotemporal changes in continental and marine environment of CP, as well as existence of possible connections between CP sedimentary basins and World Ocean. (e.g., Balla 1984; Ratschbacher et al., 1991a,b; Tari 1993; Csontos 1992; Fodor et al. 1998, Csontos et al. 2002; Rögl 1998; Popov et al. 2004; Márton et al. 2007; Harzhauser and Piller 2007; Schmid et al. 2008; Ustaszewski et al. 2008; Mandic et al. 2012; Rybár et al. 2015; Klučiar et al. 2016; Hók et al. 2016; Kováč et al. 2016, 2017b, 2018b, 2018c; Sant et al. 2017, Šujan et al. 2021b).

In the future we can assume that the challenge for further progress should be continuation in the modern detailed investigation in the field and laboratory, as well as in preparing new hypotheses based on the advance in multidisciplinary geological research.

Acknowledgement: The study was supported by the Slovak Research and Development Agency (SRDA/APVV) under contracts No. APVV-16-0121, APVV-0099-11, APVV-20-0079, APVV-14-0118, APVV-20-0120, SK-HU-2013-0020 and SK-AT-2017-0010.

References:

Balla, Z. 1984. The Carpathian loop and the Pannonian basin: a kinematic analysis. *Geophysical Transactions*, 30, 4, 313–353.

Brlek, M., Kutterolf, S., Gaynor, S., Kuiper, K., Belak, M., Brčić, V., Holcová, K., Wang, K-L., Bakrač, K., Hajek-Tadesse, V., Mišur, UI., Horvat, M., Šuica, S. & Schaltegger, U. 2020. Miocene syn-rift evolution of the North Croatian Basin (Carpathian-Pannonian Region): new constraints from Mts. Kalnik and Požeška gora volcaniclastic record with regional implications. *International Journal of Earth Sciences*, 109, 2775–2800.

Csibri, T., Rybár, S., Šarinová, K., Jamrich, M., Sliva, L. & Kováč, M. 2018. Miocene fan delta conglomerates in the north-western part of the Danube Basin: provenance, paleoenvironment, paleotransport and depositional mechanisms. *Geologica Carpathica*, 69, 5, 467–482.

Csibri, T., Ruman, A., Hudáčková, N., Jamrich, M., Sliva, Ľ., Šarinová, K. & Kováč, M. 2022. Deltaic systems of the northern Vienna Basin: The lower-middle Miocene conglomerate bodies. *Geologica Carpathica,* 73, 245–269.

Csontos, L., Nagymarosy, A., Horváth, F. & Kováč, M. 1992. Tertiary evolution of the Intra-Carpathian area: a model. *Tectonophysics*, 208, 221–241.

Csontos, L., Márton, E., Wórum, G. & Benkovics, L. 2002. Geodynamics of SW-Pannonian inselbergs (Mecsek and L. Villány Mts, SW Hungary): Inferences from a complex structural analysis, EGU Stephan Mueller Special Publication Series, 3, 227–245, Fodor, L., Jelen, B., Márton, E., Skaberne, D., Čar, J. & Vrabec, M. 1998. Miocene-Pliocene tectonic evolution of the Slovenian Periadriatic fault: Implications for Alpine-Carpathian extrusion models. *Tectonics*, 17, 5, 690–709.

Fordinál, K., Kráľ, J., Harčová, E., Čech, P., Zieliński, G. & Nagy, A. 2014. $^{87}Sr/^{86}Sr$, $\delta^{13}C$ a $\delta^{18}O$ in mollusc fossil shells from marine, brackish and freshwater environments from the Western Carpathians Tertiary sequences. *Mineralia Slovaca*, 46, 23–44. (in Slovak with Englis summary).

Garefalakis, Ph. & Schlunegger, F. 2019. Tectonic processes, variations in sediment flux, and eustatic sea level recorded by the 20 Myr old Burdigalian transgression in the Swiss Molasse basin. *Solid Earth*, 10, 2045–2072.

Harzhauser, M. & Piller, W.E. 2007. Benchmark data of a changing sea – Palaeogeography, Palaeobiogeography and events in the Central Paratethys during the Miocene. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 253, 8–31.

Hofmayer, F., Kirscher, U., Sant, K., Krijgsman, W., Fritzer, T., Jung, D., Weissbrodt, V. & Reichenbacher, B. 2019. Three-dimensional geological modeling supports a revised Burdigalian chronostratigraphy in the North Alpine Foreland Basin. International Journal of Earth Sciences. *International Journal of Earth Sciences*, 108, 2627–2651.

Hohenegger, J., Rögl, F., Ćorić, S., Pervesler, P., Lirer, F., Roetzel, R., Scholger, R. & Stingl, K. 2009. The Styrian Basin: A key to the Middle Miocene (Badenian/Langhian) Central Paratethys transgressions. *Austrian Journal of Earth Sciences*, 102, 102–132.

Hohenegger. J., Ćorić. S. & Wagreich. M. 2014. Timing of the Middle Miocene Badenian Stage of the Central Paratethys. *Geologica Carpathica*, 65, 1, 55–66.

Hók, J., Kováč, M., Pelech, O., Pešková, I., Vojtko, R. & Králiková, S. 2016. The Alpine tectonic evolution of the Danube Basin and its northern periphery (southwestern Slovakia). *Geologica Carpathica*, 67, 5, 495–505.

Hudáčková, N., Holcová, K., Halásová, K., Kováčová, M., Doláková, N., Trubač, J., Rybár, S., Ruman, A., Stárek, D., Šujan, M., Jamrich, M. & Kováč, M. 2020. The Pannonian Basin System northern margin paleogeography, climate, and depositional environments in the time range during MMCT (Central Paratethys, Novohrad-Nógrád Basin, Slovakia). *Palaeontologia Electronica*, 23, 3, a50, 10.26879/1067.

Ivančič, K., Trajanova, M., Corić, S., Rožić, B. & Šmuc, A. 2018. Miocene paleogeography and biostratigraphy of the Slovenj Gradec Basin: a marine corridor between the Mediterranean and Central Paratethys. *Geologica Carpathica*, 69, 528–544.

Joniak, P., Šujan, M., Fordinál, K., Braucher, R., Rybár, S., Kováčová, M., Kováč, M. & AsterTeam 2020. The age and paleoenvironment of a late Miocene floodplain alongside Lake Pannon: Rodent and mollusk biostratigraphy coupled with authigenic $^{10}Be/^{9}Be$ dating in the northern Danube Basin of Slovakia. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 538, 109482.

Klučiar, T., Kováč, M., Vojtko, R., Rybár, S., Šujan, M. & Králiková, S. 2016. The Hurbanovo–Diösjenő Fault: A crustal-scale weakness zone at the boundary between the Central Western Carpathians and Northern Pannonian Domain. *Acta Geologica Slovaca*, 8, 1, 59–70.

Kocsis, L., Vennemann, T.W., Hegner, E., Fontignie, D. & Tütken, T. 2009. Constraints on Miocene oceanography and climate in the Western and Central Paratethys: O-, Sr-, and Nd-isotope compositions of marine fish and mammal remains. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 271, 117–129.

Kopecká, J., Holcová, K., Brlek, M., Scheiner, F., Ackerman, L., Rejšek, J., Milovský R., Baranyi, V., Gaynor, S., Galović, I., Brčić V., Belak, M. & Bakrač, K. 2022. A case study of paleoenvironmental interactions during the Miocene Climate Optimum in southwestern Paratethys. *Global and Planetary Change*, 211, 103784.

Kováč, M., Baráth, I., Harzhauser, M., Hlavatý, I. & Hudáčková, N. 2004. Miocene depositional systems and sequence stratigraphy of the Vienna Basin. *CFS Courier Forschungsinstitut Senckenberg*, 246, 187–212.

Kováč, M., Andreyeva-Grigorovich, A., Bajraktarević, Z., Brzobohatý, R., Filipescu, S., Fodor, L., Harzhauser, M., Nagymarosy, A., Oszczypko, N., Pavelić, D., Rögl, F., Saftić, B., Sliva, Ľ. & Studencka, B. 2007. Badenian evolution of the Central Paratethys Sea: paleogeography, climate and eustatic sea-level changes. *Geologica Carpathica*, 58, 6, 579–606.

Kováč, M., Plašienka, D., Soták, J., Vojtko, R., Oszczypko, N., Less, Gy., Ćosović, V., Fügenschuh, B. & Králiková, S. 2016. Paleogene palaeogeography and basin evolution of the Western Carpathians, Northern Pannonian domain and adjoining areas. *Global and Planetary Change*, 140, 9–27.

Kováč, M., Hudáčková, N., Halásová, E., Kováčová, M., Holcová, K., Oszczypko-Clowes, M., Báldi, K., Less, Gy., Nagymarosy, A., Ruman, A., Klučiar, T. & Jamrich, M. 2017a. The Central Paratethys palaeoceanography: a water circulation model based on microfossil proxies, climate, and changes of depositional environment. *Acta Geologica Slovaca*, 9, 2, 75–114.

Kováč, M., Márton, E., Oszczypko, N., Vojtko, R., Hók, J., Králiková, S., Plašienka, D., Klučiar, T., Hudáčková, N. & Oszczypko-Clowes, M. 2017b. Neogene palaeogeography and basin evolution of the Western Carpathians, Northern Pannonian domain and adjoining areas. *Global and Planetary Change*, 155, 133–154.

Kováč, M., Halásová, E., Hudáčková, N., Holcová, K., Hyžný, M., Jamrich, M. & Ruman, A. 2018a. Towards better correlation of the Central Paratethys regional time scale with the standard geological time scale of the Miocene Epoch. *Geologica Carpathica*, 69, 3, 283–300.

Kováč, M., Márton, E., Klučiar, T. & Vojtko, R. 2018b. Miocene basin opening in relation to the north-eastward tectonic extrusion of the ALCAPA Mega-Unit. *Geologica Carpathica*, 69, 3, 254–263.

Kováč, M., Rybár, S., Halásová, E., Hudáčková, N., Šarinová, K., Šujan, M., Baranyi, V., Kováčová, M., Ruman, A., Klučiar T. & Zlinská, A. 2018c. Changes in Cenozoic depositional environment and sediment provenance in the Danube Basin. *Basin Research*, 30, 97–131.

Krézsek, C. & Bally, A.W. 2006. The Transylvanian Basin (Romania) and its relation to the Carpathian fold and thrust belt: Insights in gravitational salt tectonics. *Marine and Petroleum Geology*, 23, 405–442.

Lukács, R., Harangi, S., Gál, P., Szepesi, J., Di Capua, A., Norini, G., Sulpizio, R., Groppelli, G. & Fodor, L. 2022. Formal definition and description of lithostratigraphicunits related to the Miocene silicic pyroclastic rocksoutcropping in Northern Hungary: A revision. *Geologica Carpathica*, 73, 2, 137–158.

Mandic, O., de Leeuw, A., Bulić, J., Kuiper, K.F., Krijgsman, W. & Jurišić-Polšak, Z. 2012. Paleogeographic evolution of the Southern Pannonian Basin: ^{40}Ar/^{39}Ar age constraints on the Miocene continental series of Northern Croatia. *International Journal of Earth Sciences*, 101, 1033–1046.

Márton, E. 2007. Correlation of Miocene Volcanics in the Area of the North Hungary Paleogene Basin by the Combination of Palaeomagnetic Marker Horizons and Magnetic Polarities. *Joannea Geologie & Paläontologie*, 9, 63–65.

Nováková, P., Rybár, S., Šarinová, K., Nagy, A., Hudáčková, N., Jamrich, M., Teodoridis, V., Kováčová, M., Šujan, M., Vlček, T. & Kováč, M. 2020. The late Badenian-Sarmatian (Serravallian) environmental transition calibrated by sequence stratigraphy (Eastern Danube Basin, Central Paratethys). *Geologica Carpathica*, 71, 4, 291–313.

Oszczypko, N., Uchman, A. & Bubniak, I. 2014. The Dobrotiv Formation (Miocene) in the Boryslav-Pokuttya and Sambir nappes of the Ukrainian Carpathians: a record of sedimentary environmental change in the development of the Carpathian Foredeep Basin. *Geological Quarterly*, 58, 3, 393–408.

Oszczypko, N., Uchman, A. & Bubniak, I. 2016. The Stebnyk For ma tion (Mio cene) in the Boryslav-Pokuttya and Sambir nappes of the Ukrainian Carpathians: a record of environ mental change in the Carpathian Foredeep. *Geological Quarterly*, 60, 2, 473–492.

Ozdínová, S. & Soták, J. 2014. Oligocene–Early Miocene Ppanktonic microbiostratigraphy and paleoenvironments of the South Slovakian Basin (Lučenec Depression). *Geologica Carpathica*, 65, 6, 451–470.

Nováková, P., Rybár, S., Šarinová, K., Nagy, A., Hudáčková, N., Jamrich, M., Teodoridis, V., Kováčová, M., Šujan, M., Vlček, T. & Kováč, M. 2020. The late Badenian-Sarmatian (Serravallian) environmental transition calibrated by sequence stratigraphy (Eastern Danube Basin, Central Paratethys). *Geologica Carpathica*, 71, 4, 291–313.

Pálfy, J., Mundil, R., Renne, P.R., Bernor, R.L., Kordos, L. & Gasparik, M. 2007. U–Pb and ^{40}Ar/^{39}Ar dating of the Miocene fossil track site at Ipolytarnóc (Hungary) and its implications. *Earth and Planetary Science Letters*, 258, 1–2, 160–174.

Popov, S.V., Rögl, F., Rozanov, A.Y., Steininger, F.F., Shcherba, I.G. & Kováč, M. 2004. Lithological-paleogeographic maps of ParaTethys. *CFS Courier Forschungsinstitut Senckenberg*, 250, 1–46, maps 1-10.

Popov, S.V., Antipov, M.P., Zastrozhnov, A.S., Kurina, E.E. & Pinchuk, T.N. 2010. Sea-level fluctuations on the northern shelf of the Eastern Paratethys in the Oligocene-Neogene. *Stratigraphy and Geological Correlation*, 18, 200–224.

Püspöki, Z., Hámor-Vidó, M., Pummer, T., Sári, K., Lendvay, P., Selmeczi, I., Detzky, G., Gúthy, T., Kiss, J., Kovács, Zs., Prakfalvi, P., McIntosh, R.W., Buday-Bódi, E., Báldi, K., Markos, G. 2017. A sequence stratigraphic investigation of a Miocene formation supported by coal seam quality parameters – Central Paratethys, N-Hungary. *International Journal of Coal Geology*, 179, 196–210.

Ratschbacher, L., Merle, O., Davy, P. & Cobbold, P. 1991a. Lateral extrusion in the Eastern Alps; part 1: Boundary conditions and experiments scaled for gravity. *Tectonics*, 10, 2, 245–256.

Ratschbacher, L., Frisch, W., Linzer, H.G. & Merle, O. 1991b. Lateral extrusion in the Eastern Alps; part 2: Structural analysis. *Tectonics*, 10, 2, 257–271.

Rögl, F. 1998. Palaeogeographic Considerations for Mediterranean and Paratethys Seaways (Oligocene to Miocene). *Annalen des Naturhistorischen Museums in Wien*, 99A, 279–310.

Ruman, A., Ćorić, S., Halásová, E., Harzhauser, M., Hudáčková, N., Jamrich, M., Palzer-Khomenko, M., Kranner, M., Mandic, O., Rybár, S., Šimo, V., Šujan, M. & Kováč, M. 2021. The "Rzehakia beds" on the northern shelf of the Pannonian Basin: biostratigraphic and palaeoenvironmental implications. *Facies*, 67, 1, 1–22.

Rybár, S., Halásová, E., Hlavatá Hudáčková, N., Kováč, M., Šarinová, K. & Šujan, M.. 2015. Biostratigraphy, sedimentology and paleoenvironments of the northern Danube Basin: Ratkovce 1 well case study. *Geologica Carpathica*, 66, 1, 51–67.

Rybár, S., Kováč, M., Šarinová, K., Halásová, E., Hudáčková, N., Šujan, M., Kováčová, M., Ruman, A. & Klučiar, T. 2016. Neogene changes in paleogeography, paleoenvironment and the provenance of sediment in the northern Danube Basin. *Bulletin of Geosciences*, 91, 2, 367–398.

Rybár, S., Šarinová K., Sant, K., Kuiper, K.F., Kováčová, M.,Vojtko, R., Reiser, M.K., Fordinál, K., Teodoridis, V., Nováková, P., Vlček, T. 2019. New ^{40}Ar/^{39}Ar, fission track and sedimentological data on a middle Miocene tuff occurring in the Vienna Basin: implications for the North-Western Central Paratethys region. *Geologica Carpathica*, 70, 5, 386–404.

Sant, K., Palcu, D.V., Mandic, O. & Krijgsman, W. 2017. Changing seas in the Early–Middle Miocene of Central Europe: a Mediterranean approach to Paratethyan stratigraphy. *Terra Nova*, 29, 273–281.

Sant, K., Kuiper, K.F., Rybár, S., Grunert, P., Harzhauser, M., Mandic, O., Jamrich, M., Šarinová, K., Hudáčková, N. & Krijgsman, W. 2020. ^{40}Ar/^{39}Ar geochronology using high sensitivity mass spectrometry: Examples from middle Miocene horizons of the Central Paratethys. *Geologica Carpathica*, 71, 2, 166–182

Šarinová, K., Hudáčková, N., Rybár, S., Jamrich, M., Jourdan, F., Frew, A., Mayers, C., Ruman, A., Subová, V. & Sliva, Ľ. 2021a. ^{40}Ar/^{39}Ar dating and palaeoenvironments at the boundary of the early-late Badenian (Langhian-Serravallian) in the northwest margin of the Pannonian basin system. *Facies*, 67, 29.

Šarinová, K., Rybár, S., Jourdan, F., Frew, A., Mayers, C., Kováčová, M., Lichtman, B., Nováková, P. & Kováč, M. 2021b. ^{40}Ar/^{39}Ar geochronology of Burdigalian paleobotanical localities in the central Paratethys (south Slovakia). *Geologica Acta*, 19, 1–19.

Schmid, S.M., Bernoulli, D., Fügenschuh, B., Matenco, L., Schefer, S., Schuster, R., Tischler, M. & Ustaszewski, K. 2008. The Alpine-Carpathian-Dinaridic orogenic system: correlation and evolution of tectonic units. *Swiss Journal of Geosciences*, 101, 1, 139–183.

Sóron, A.S. 2011. Paleoenvironmental and stratigraphic investigations of the foraminiferal fauna from the Karpatian (Lower Miocene) Garáb Schlier Formation of the Mátraverebély-122 (Mv-122) borehole (North Hungary). *Central European Geology*, 54, 3, 211–231.

Šujan, M., Braucher, R., Tibenský, M., Fordinál, K., Rybár, S., Kováč, M. & AsterTeam 2020. Effects of spatially variable accommodation rate on channel belt distribution in an alluvial sequence: Authigenic 10Be/9Be-based Bayesian age-depth models applied to the upper Miocene Volkovce Fm. (northern Pannonian Basin System, Slovakia). *Sedimentary Geology*, 397, 105566.

Šujan, M., Braucher, R., Mandic, O., Fordinál, K., Brixová, B., Kyška Pipík, R., Šimo, V., Jamrich, M., Rybár, S., Klučiar, T., Aster Team, Ruman, A., Zvara, I. & Kováč, M. 2021a. Lake Pannon transgression on the westernmost tip of the Carpathians constrained by biostratigraphy and authigenic ^{10}Be/^{9}Be dating (Central Europe). *Rivista Italiana di Paleontologia e Stratigrafia*, 127, 3, 627–653.

Šujan, M., Rybár, S., Kováč, M., Bielik, M., Majcin, D., Minár, J., Plašienka, D., Nováková, P. & Kotulová, J. 2021b. The polyphase rifting and inversion of the Danube Basin revised. *Global and Planetary Change*, 196, 103375.

Šujan, M., Braucher, R., Kováč, M., Bourlès, D., Rybár, S., Guillou, V. & Hudáčková, N. 2016. Application of the authigenic 10Be/9Be dating method to Late Miocene–Pliocene sequences in the northern Danube Basin (Pannonian Basin System): Confirmation of heterochronous evolution of sedimentary environments. *Global and Planetary Change*, 137, 35–53.

Subová, V., Rybár, S., Šarinová, K., Hudáčková, N., Jamrich, M., Sliva, Ľ., Šály, B. & Hlavatý, I. 2022. Evolution of the lower Badenian depositional system in the East Slovakian Basin: Implications for reservoir rock potential. *Geologica Carpathica*, 73, 4, 319–352.

Sztanó, O., Kováč, M., Magyar, I., Šujan, M., Fodor, L., Uhrin, A., Rybár, S., Csillag, G. & Tőkés, L. 2016. Late Miocene sedimentary record of the Danube / Kisalföld Basin: interregional correlation of depositional systems, stratigraphy and structural evolution, *Geologica Carpathica*, 67, 6, 525–542.

Tari, G., Bada, G., Beidinger, A., Csizmeg, J., Danišik, M., Gjerazi, I., Grasemann, B., Kováč, M., Plašienka, D., Šujan, M. & Szafián, P. 2021. The connection between the Alps and the Carpathians beneath the Pannonian Basin: Selective reactivation of Alpine nappe contacts during Miocene extension. *Global and Planetary Change*, 103401.

Tari, G., Báldi, T. & Báldi-Beke, M. 1993. Paleogene retroarc flexural basin beneath the Neogene Pannonian Basin: a geodynamic model. *Tectonophyscs*, 226, 433–455.

TimeScale Creator 8.0. https://timescalecreator.org/index/index.ph

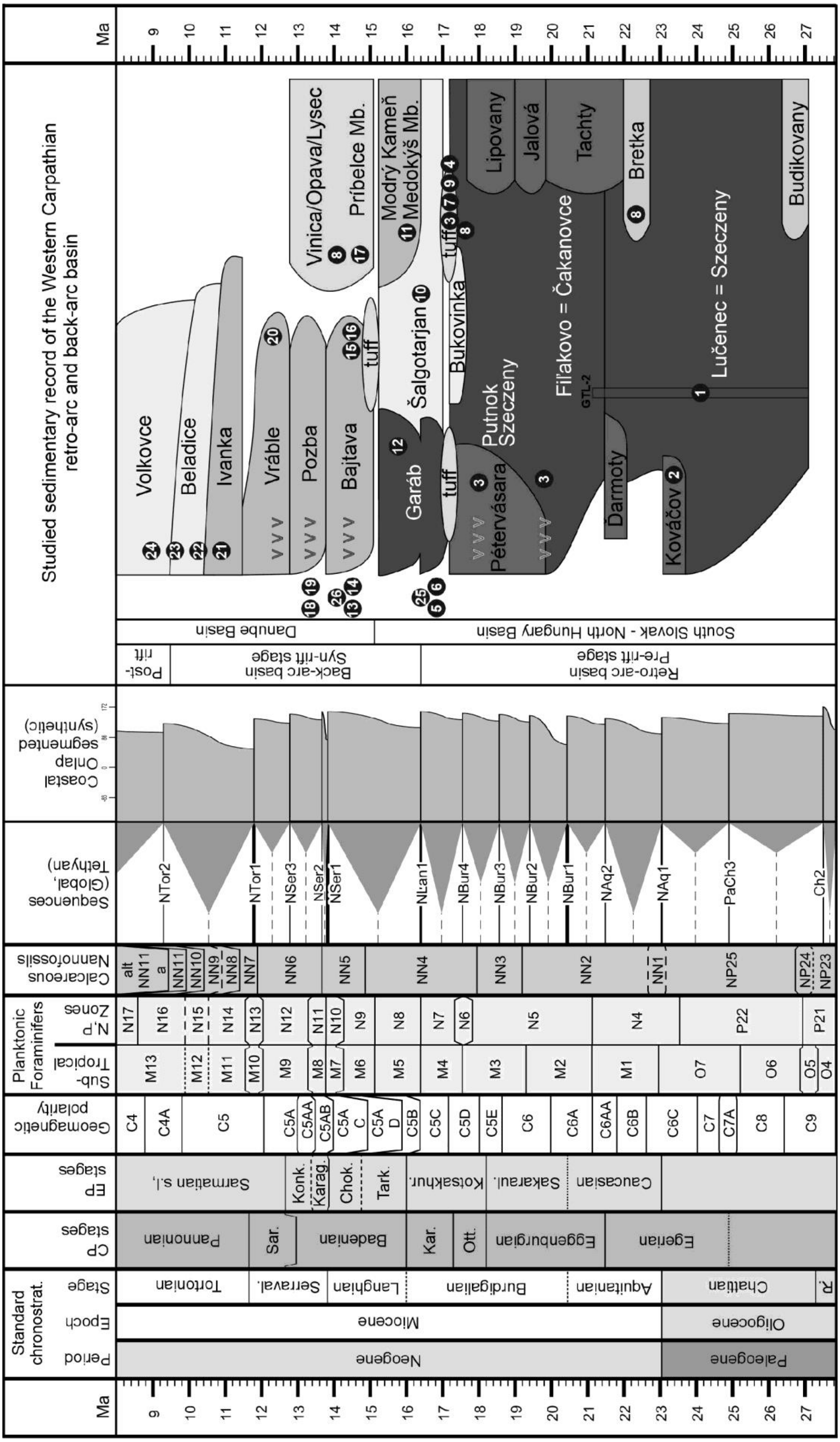
Ustaszewski, K., Schmid, S.M., Fügenschuh, B., Tischler, M., Kissling, E. & Spakman W. 2008. A map-view restoration of the Alpine-Carpathian-Dinaridic system for the Early Miocene. *Swiss Journal of Geosciences*, 101, suppl. 1, 273–294.

Vlček, T., Šarinová, K., Rybár, S., Hudáčková, N., Jamrich, M., Halásová, E., Šujan, M., Franců, J., Nováková, P., Sliva, Ľ., Kováč, M. & Kováčová, M. 2020. Paleoenvironmental evolution of Central Paratethys Sea and Lake Pannon during the Cenozoic. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 559, 109892.

Vlček, T., Kováčová, M., Šarinová, K., Rybár, S., Hudáčková, N., Ruman, A., Jamrich, M. & Franců, J. 2022. Multiproxy constraints on Central Paratethys Sea and Lake Pannon paleoclimate and paleoenvironment transitions during the Middle-Late Miocene (Danube Basin, Slovakia). *Palaeogeography, Palaeoclimatology, Palaeoecology*, 600, 111058.

Vass, D. 2002. *Lithostratigraphy of Western Carpathians: Neogene and Buda Paleogene*. SGUDS, Bratislava, 202 pp. (in Slovak).

Figure 1 (next page): Scheme of the studied Western Carpathians back-axis basins sedimentary record. Created using the TimeScale Creator and based on 1. Ozdínová and Soták 2014; 2. Fordinál et al. 2014; 3. Lukács, R. et al. 2022; 4. Kocis et al. 2009; 5. Csibri et al. 2022; 6. Csibri et al. 2018; 7. Pálfy et al. 2007; 8. Vass 2002; 9. Šarinová et al. 2021b; 10. Püspöki et al. 2017; 11. Ruman et al., 2021; 12. Sóron 2011; 13. Rybár et al. 2019; 14. Rybár et al. 2015; 15. Kováč et al. 2018c; 16. Vlček et al. 2022; 17. Hudáčková et al. 2020; 18. Sant et al. 2020; 19. Šarinová et al. 2021a; 20. Nováková et al. 2020; 21. Šujan et al. 2021a; 22. Šujan et al. 2020; 23. Šujan et al. 2021b; 24. Sztanó et al. 2022; 25. Kováč et al. 2004; 26. Kováč et al. 2007.


Studied sedimentary record of the Western Carpathian retro-arc and back-arc basin
Ma
Standard chronostrat.
Period
Epoch
Stage
CP stages
EP stages
Geomagnetic polarity
Planktonic Foraminifers
Sub-Tropical
N,P Zones
Calcareous Nannofossils
Sequences (Global, Tethyan)
Coastal Onlap segmented (synthetic)
Neogene
Paleogene
Miocene
Oligocene
Tortonian
Serraval.
Langhian
Burdigalian
Aquitanian
Chattian
R.
Pannonian
Sar.
Badenian
Kar.
Ott.
Eggenburgian
Egerian
Sarmatian s.l.
Konk.
Karag.
Chok.
Tark.
Kotsakhur.
Sakaraul.
Caucasian
Volkovce
Beladice
Ivanka
Vráble
Pozba
Bajtava
tuff
Garáb
Šalgotarjan
Bukovinka
Putnok
Szeczeny
Pétervására
Fiľakovo = Čakanovce
Lučenec = Szeczeny
Ďarmoty
Kováčov
Vinica/Opava/Lysec
Príbelce Mb.
Modrý Kameň
Medokýš Mb.
Lipovany
Jalová
Tachty
Bretka
Budikovany
GTL-2
Danube Basin
South Slovak - North Hungary Basin
Back-arc basin
Syn-rift stage
Post-rift
Retro-arc basin
Pre-rift stage

Paleoenvironmental evolution of the Vienna Basin during the Miocene

MATTHIAS KRANNER[1], MATHIAS HARZHAUSER[1], OLEG MANDIĆ[1], WERNER E. PILLER[2], PHILIPP STRAUSS[3] and WOLFGANG SIEDL[3]

1 – Geological-Palaeontological Department, Natural History Museum Vienna, Burgring 7, 1010 Vienna, Austria; e-mail: matthias.kranner@nhm-wien.ac.at

2 – Institute of Earth Sciences (Geology and Palaeontology), University of Graz, NAWI Graz Geocenter, Heinrichstraße 26, 8010 Graz, Austria

3 – OMV Exploration and Production GmbH, Trabrennstraße 6-8, 1020 Vienna, Austria

The Vienna asin (VB) is an about 200 km long and 55 km wide, rhomboid extensional basin, covering large parts of eastern Austria and extending northwards into the Czech Republic and eastwards to Slovakia. It originated during the early and middle Miocene and is composed of several horst and graben structures forming different subbasins. Each subbasin yields an own geodynamic evolution and deviating paleobathymetric developments during the Miocene marking the VB as one of the largest oil and gas fields in on shore Europe.

During the last decades the OMV AG is leading in the investigation of the northern and central VB and numerous boreholes with up to 8,500 m depth (Zistersdorf ÜT 2a) were studied (mostly unpublished OMV internal reports). Still, the correlation of Neogene deposits throughout the basin remained ambiguous in regards of biostratigraphic correlation, paleoecological and paleobathymetrical reconstruction, due to the complex fault systems of the VB. To resolve persistent shortcomings in correlation of target horizons, a project was initiated covering 717 samples of 54 wells roughly aligned on a NNE to SSW transect. Micropaleontological data have been combined with core-log data, such as spontaneous potential, resistivity as well as modern 3D seismic data leading to the first continuous reconstruction of paleoenvironmental evolution of the VB from the early Miocene to the middle Miocene spanning 6.4 million years.

Beside paleoenvironmental and biostratigraphic analyses, we applied transfer functions using benthic and planktonic foraminifers to analyze the water depth evolution and ecological trends like oxygen availability, salinity, trophic levels, bottom and sea surface temperature. Plankton-Benthos ratio was also applied to gather information of bathymetrical changes but showed troubling results. Hence, we propose not to use P/B ratio as main indictor for sea-level fluctuation reconstructions in highly active marginal areas like the VB. Using the transfer function of benthic foraminifers, dramatic changes in the depth profile with concomitant ecological changes through time, which coincide with shifts of prevailing tectonic regimes, could be observed. Bathyal conditions were established during the early Miocene piggy-back stage and the early middle Miocene extensional phase. A clear shallowing trend from upper bathyal to inner neritic conditions occurred during the middle Miocene extensional tectonic phase.

Bottom water temperatures indicate a cooling during the early and middle Badenian (Langhian), which seemingly contradicts the global warming of the Middle Miocene Climatic Optimum (MMCO) and a subsequent warming, which contrasts the expected trend following the cooling of the Middle Miocene Climatic Transition. Both trends are discussed as result of bathymetric evolution of the VB and intense upwelling during the early and middle Badenian.

Acknowledgement: This project is financed by the OMV-AG.

Geological structure of the junction zone between the Tatric and Veporic units in the Nízke Tatry Mts. (Western Carpathians)

KATARÍNA KRIVÁŇOVÁ, RASTISLAV VOJTKO, DAVID MILOŠ DROPPA and SILVIA GERÁTOVÁ

Comenius University, Faculty of Natural Sciences, Department of Geology and Paleontology, Ilkovičova 6, 842 15 Bratislava, Slovak Republic; e-mail: katarina.krivanova@gmail.com

The Nízke Tatry Mts. is a mountain range that extends in the central part of the Western Carpathians. From a geomorphological point of view, the Nízke Tatry Mts. range is divided into two parts. The eastern part is referred to as the Kráľovohoľské Tatry Mts. and the western part is called the Ďumbierske Tatry Mts. (Mazúr and Lukniš 1986). The study area is located in the contact zone of both parts. The geographical and geological boundary between the mentioned sub-units roughly follows the Čertovica fault. It can be observed directly on the surface in the area between Mýto pod Ďumbierom and Vyšná Boca villages. This important fault zone is formed by several slips, which was created in the mid-Cretaceous period (Albian-Cenomanian) and represents broader contact zone between the Tatric and Veporic units (Maheľ 1986).

The Tatric crystalline basement is formed by extensive Lower Carboniferous granite bodies in the northern part, while its southern part consists of metamorphosed rocks of the Lower Paleozoic age. The Tatric cover sequence is preserved only rudimentary, however, in the area of Červená Magura Mt. a more continuous cover sequence is outcropped and ranging from the Permian to Cretaceous. The Tatric Unit is overridden by the Veporic Unit along the Čertovica thrust Cretaceous in age. Based on the superposition and Variscan/Alpine metamorphic overprint, the Veporic Unit is divided into the northern and southern parts (Zoubek 1953).

The Northern Veporic Subunit is composed mainly of metamorphosed sediments, volcanic rocks with Upper Devonian to Lower Carboniferous granite bodies. The structurally lowest member of the Northern Veporic crystalline basement overlying the Tatric Unit composed of the Ľubietová Complex, which consists mainly of originally high-grade metamorphosed paragneisses, amphibolites, migmatites, and orthogneisses. Structurally higher position in the crystalline basement is occupied by the Jánov grúň Complex, which is composed of diaphtoritised metapelites with usually mylonitised granite intrusions. This complex is covered by various gneissose-mica schists and amphibolites of the Hron Complex, which form the highest structural portion of the Northern Veporic Subunit in the Alpine structure. Based on the Variscan structure, the crystalline basement is considered a part of the middle gneissose-mica schist lithotectonic unit (Hron Complex) and relics of upper lithotectonic unit with diaphtorites (Ľubietovský and Jánov grúň Complex). The Variscan crystalline basement is covered by the Veľký Bok cover sequence with stratigraphic range from Permian to mid-Cretaceous. The Alpine metamorphic overprint is low and comprise lower green schist facies conditions.

From the structural point of view the Southern Veporic Subunit forms the highest element in the Nízke Tatry crystalline basement and is mainly composed of mylonitised granitoid rocks and relics of the middle gneissose-mica schist lithotectonic unit. The Southern Veporic crystalline basement is covered by the Federáta cover sequence (Late Carboniferous – Late Triassic). The structure of The Nízke Tatry Mts. is completed by superficial nappes of the Fatric, Hronic and Silicic units.

The geological structure of the Nízke Tatry Mts. is a result of a long-term and multi-stage magmatogenic, metamorphic, and tectonic evolution. The studied area was affected by at least two orogenetic stages – Variscan and Alpine. Based on the structural analysis, it was possible to determine several deformation events.

Based on the field and microscopical observation of planar (foliation, schist, cleavage, etc.) and linear (lineation, fold axes, etc.) secondary (tectonic) structures, their relationships and cross-cutting criteria, it was possible to reveal the older Variscan and younger Alpine deformation.

In the study area, the Variscan structure can by characterised by pervasive metamorphic foliation S_2^V locally with preserved isoclinal and root-less folds of the S_1^V planar structure. The stretching and mineral lineations are generally oriented in NNE – SSW direction. These planar and linear structures are intensively folded on many places. The Alpine structure can be characterised by zonal to pervasive planar structures S_1^A followed by cleavage and evolution of S-C structures of S_2^A generally with a southeast inclination and top-to-the-northwest direction of movement. The shortherning in NNW – SSE direction is also proved by asymmetric folds with ENE – SWS orientation of fold axes and intersection lineations.

The last observed Alpine structures S_3^A are related to extension and exhumation of the Tatric basement with transport top-to-the-east defined by the Alpine stretching lineation (L_3^A).

Acknowledgement: The study was supported financially by the Slovak Research and Development Agency (APVV) under contracts Nos. APVV-17-0170 and APVV-21-0281 and the Slovak Academy of Sciences (VEGA) under contract No. VEGA 1/0346/20 and Grant UK 330/2021 Geológia a tektonika styčnej zóny tatrika a veporika v oblasti Nízkych Tatier.

References:

Maheľ, M. 1986. Geologická stavba československých Karpát, Paleoalpínske jednotky 1., *Veda, Vydavateľstvo Slovenskej akadémie* vied, Geologický ústav Dionýza Štúra, Bratislava, 503 s.

Mazúr, E. & Lukniš, M. 1980. Geomorfologické jednotky. *In:* Mazúr, E., (Ed.): *Atlas Slovenskej socialistickej republiky*. Bratislava (SAV a SÚGK), pp. 54–55.

Zoubek, V., 1953. Předběžná zpráva o výzkumu východní části nízkotatranského jaderného pohoří. *Věstník SGÚ* 28, Praha.

Modal composition of clastic sediment as an indicator of tectonic and climatic events during the post-rift development of the Pannonian Basin System; the example from the North Croatian Basin, Republic of Croatia

TOMISLAV KUREČIĆ[1] and MARIJAN KOVAČIĆ[2]

1 – Croatian Geological Survey – HGI-CGS, Sachsova 2, Zagreb, Croatia; e-mail: tkurecic@hgi-cgs.hr

2 – Department of Geology, Faculty of Science, University of Zagreb, Horvatovac 102b, Zagreb, Croatia

The North Croatian Basin (NCB) is located in the southwestern part of the Pannonian Basin System (PBS). During the postrift phase of its development from the Late Miocene onwards, the basin accumulated a sequence of clastic deposits more than one kilometer thick, initially deposited in a brackish lake, then a freshwater lake, and finally in an alluvial depositional environment (Pavelić and Kovačić 2018). The aim of this work was to determine the composition and origin of this material and to define its origins by analyzing the modal composition and textural features.

The results showed that the Late Miocene sands are texturally mature and have a uniform modal composition throughout the basin. Their composition is dominated by quartz and stable rocks fragments, and heavy minerals are dominated by garnets, epidote and amphibole. The detritus was formed by weathering of metamorphic and older clastic sedimentary rocks located to the north and northwest of the North Croatian Basin, in the area of the Eastern Alps and Western Carpathians.

The Pliocene sediments vary greatly in composition in different parts of the NCB. The northwestern part of the basin was at the time still filled with texturally and mineralogically mature sandy detritus transported from the northwest, but the absence of garnet and epidote, with a significant increase in the occurrence of kyanite, staurolite and rutile indicates different source rocks. The Pliocene sands from the southwestern part of the NCB are texturally immature. In addition to material of alpine origin, they also contain carbonate clastic detritus and, in the heavy mineral community, chrom spinel. This detritus originates from nearby sources located to the west and south of the basin in the Inner Dinarides area. The composition and origin of detritus in the eastern part of the NCB is similar to the detritus from the southwestern part of basin. The presence of pyroxene and chrom spinel in clastic material from eastern part of the basin indicates that part of material formed by weathering of basic igneous rocks located to the south in the Inner Dinarides area.

During the Pleistocene, loess was deposited on most of the NCB, the sources of which were located in the area of the Danube River floodplain in the northern part of the PBS. Besides, mineralogically and texturally immature sandy and gravelly debris of different modal composition was deposited on the margins of the mountains present within the basin and on the southern margin of the basin. The composition of this debris indicates that it is locally derived from the uplifted basement rocks.

The observed differences in the modal composition and textural features of the clastic detritus that filled the area of the NCB in the post-rift phase of the basin's development indicate intense tectonic activity and climatic changes throughout the late Miocene, Pliocene, and Pleistocene. During the slowdown of basin floor subsidence and the onset of basin inversion at the end of the Miocene and in the Pliocene, a relatively warm and humid climate contributed to the increased erosion of the elevated parts of the Alps and the Western Carpathians, supplying a large amount of clastic detritus that deposited in river systems in the study area (Kovačić et al. 2004, Tomljenović and Csontos 2001, Kurečić et al. 2021). The presence of materials of southern provenance in the composition of the Pliocene clastics suggests the contribution of the Inner Dinarides in the filling of the southern part of the NCB. The deposition of loess is an indicator of colder climatic periods in the Pleistocene. The debris formed by the erosion of pre-Neogene basement rocks of the Pannonian Basin System and accumulated around the present-day mountains in the NCB suggests intensive uplift of individual blocks and the continuation of the compressional phase of basin development in the Quaternary.

Acknowledgement: This study was supported by the Croatian Science Foundation under the SEDBAS project IP-2019-04-7042.

References:

Kovačić, M., Zupanič, J., Babić, Lj., Vrsaljko, D., Miknić, M., Hećimović, I., Avanić, R. & Brkić, M. 2004. Lacustrine basin to delta evolution in the Zagorje Basin, a Pannonian sub-basin (Late Miocene: Pontian, NW Croatia). *Facies,* 50, 19–33.

Kurečić, T., Kovačić, M. & Grizelj, A. 2021. Mineral assemblage and provenance of the pliocene Viviparus beds from the area of Vukomeričke Gorice, Central Croatia. *Geologia Croatica,* 74, 3, 253–271.

Maglay, J., Pristaš, J., Kučera, M. & Ábelová, M. 2009. Quaternary Geological Map of Slovakia - The Map of Quaternary Genetical Deposits Types 1:500,000. *Slovak Geological Survey, Bratislava*.

Pavelić, D. & Kovačić, M. 2018. Sedimentology and stratigraphy of the Neogene rift-type North Croatian Basin (Pannonian Basin System, Croatia): A review". *Marine and Petroleum Geology,* 91, 455–469.

Preliminary results from the geological and geomorphological research of the cave with blue and green speleothems (Low Tatras, Western Carpathians)

JURAJ LITTVA[1], PAVEL BELLA[1,2], ĽUDOVÍT GAÁL[1],
LAURA DUŠEKOVÁ[1,3] and PAVEL HERICH[1,4]

1 – Slovak Caves Administration, State Nature Conservancy of the Slovak Republic, Hodžova 11, 031 01 Liptovský Mikuláš, Slovak Republic; e-mail: littva@gmail.com

2 – Department of Geography, Faculty of Education, Catholic University in Ružomberok, Hrabovská cesta 1, 031 04 Ružomberok, Slovak Republic

3 – Institute of Geodesy, Cartography and Geographical Information Systems, Faculty of Mining, Ecology, Process Control and Geotechnologies, Technical University Košice, Park Komenského 19, 040 01 Košice, Slovak Republic

4 – Department of Physical Geography and Geoinformatics, Faculty of Natural Sciences, Comenius University in Bratislava, Mlynská dolina, Ilkovičova 6, 842 15 Bratislava 4, Slovak Republic

Modrá jaskyňa (Blue Cave), discovered near Malužiná village, is the only cave in Slovakia with the reported extensive occurrence of the blue and green speleothems. Orvošová et al. (2016) identified copper as a predominant chromophore and assumed the nearby Permian basalts, containing barium-sulphide ore veinlets, to be a likely source. However, some unpublished reports describe the presence of Cu, linked to the metasomatic-hydrothermal mineralisation, directly in the carbonates sampled from the borehole and the outcrops located less than 200 m from the cave (Hanáček 1963; Biely 1964). This makes the cave a speleogenetically interesting site, as the caves linked with the hydrothermal-metasomatic processes tend to be formed by non-epigene speleogenetic processes (e.g., Klimchouk et al. 2017 and references within). Moreover, the cave is located in the "key territory" for the tectonic study of the entire mountain range, near the tectonic contact of the two thick-skinned geological units (Tatricum and Veporicum) partially overlain by the thin-skinned Hronicum Unit (Vozár et al. 1983). The tectonically reworked Middle Triassic dolomitic rocks hosting the cave are one of the least studied rocks of the Hronic Unit (Havrila 2011). Therefore, the Blue Cave provides a suitable "outcrop" for studying intriguing speleogenetic and regional geological phenomena.

The speleogenetic research involved a detailed study of the cave pattern, preserved fluvial sediments and cave solution morphologies, comparing their distribution to the arrangement of the structural discontinuities and nearby surface landforms. The lithology and tectonic structures of the cave's host rock were studied directly or from a cave's 3-D model created by a mobile LIDAR scanner.

Although dolomite alteration was observed in the borehole Ma-2 (Biely 1964), no alteration or morphologies pointing to non-epigene speleogenesis were observed in the cave. These processes were either not extensive enough or were overprinted in later stages of cave evolution. The cave's position below the present-day river terrace, the overall pattern of the cave passages, and observed solutional features point to the formation mainly by slowly flowing to stagnant water below the former level of the surface stream. The presence of air traps at the top of ceiling pockets shows evidence of the repeated flooding of the cave passages in the next stage of speleogenesis after the stream's downcutting. Finally, parts of the cave were remodelled by breakdown processes enhanced by bedrock layering. The cave was formed in bedded and massive grey to dark grey dolomite dipping 30 – 40° to the east. Under the microscope, it is recrystallized dolosparite and dolomicrosparite (locally brecciated) with thin calcite veins, dark Fe-smudges, and microstylolites. Observed faults and joints in the cave are oriented to the NE–SW, NW–SE, and NNW–SSE. Prominent drag fold and tectonic breccias occur at the shallow-dipping NE–SW-striking thrusts, probably related to the nappe stacking of the Hronicum. Steeper-dipping NE–SW- and NW–SE-oriented structures likely correspond to the steep oblique to strike-slip faults that dissect and juxtapose different structural levels of the Hronicum nappe stack and lower tectonic units. Blue and green incrustations (likely secondary copper minerals) occur near these discontinuities and are occasionally smeared on their slickensides. NE–SW- and NW–SE-striking fractures are also associated with blue and green speleothems, so they likely played a significant role in the remobilisation of the copper from the bedrock.

Acknowledgement: This work was supported by the VEGA grants No. 1/0146/19 and No. 1/0340/22 and by institutional financing of the State Nature Conservancy of the Slovak Republic, Slovak Caves Administration.

References:

Biely, A. 1964. Výskum mezozoika v Nízkych Tatrách, list Horná Lehota (in Slovak). *Geological Institute of Dionýz Štúr,* Bratislava, 1–35. Archive of Geofond, archive number: 12924.

Hanáček, J. 1963. Ročná správa o geochemickom výskume karbonatických hornín v okolí Malužinej (in Slovak). *Geological Institute of Dionýz Štúr,* Bratislava, 1–15. Archive of Geofond, archive number: 11358.

Havrila, M. 2014. Hronikum: paleogeografia a stratigrafia (vrchný pelsón–tuval), štrukturalizácia a stavba. *Geologické Práce Správy* 117, 7–103.

Klimchouk, A., Palmer, A.N., De Waele, J., Auler A.S. & Audra, P. (Eds.) 2017: *Hypogene Karst Regions and Caves of the World.* Springer, Cham, 911 pp.

Orvošová, M., Milovská, S., Mikuš, T., Šmoll, J., Majerníčková, G. & Karošiak, I. 2016. Flowstones colored by metal ions in the Blue Cave, Nízke Tatry Mts., Slovakia (in Slovak, English summary). *Slovenský kras* 54, 2, 131–138.

Vozár, J., Bujnovský, J., Vozárová, A., Vaškovský, I., Hanzel, V., Šucha, P., Hanáček, J., Stankovič, J., Lukáčik, E., Planderová, E., Muška, P. & Biely, A. 1983. Vysvetlivky ku geologickej mape 1:25 000, list 36-221 /Malužiná-1/ (in Slovak). *Geological Institute of Dionýz Štúr, Bratislava*, 1–124. Archive of Geofond, archive number: 57054.

Provenance study of the Upper Cretaceous – Paleocene turbiditic deposits of the Pupov Formation (Pieniny Klippen Belt, Terchová-Zázrivá area)

JOZEF MADZIN[1] and DUŠAN PLAŠIENKA[2]

1 – Earth Science Institute, Slovak Academy of Sciences, Ďumbierska 1, 974 11 Banská Bystrica, Slovak Republic; e-mail: jozotm@gmail.com

2 – Department of Geology and Paleontology, Faculty of Natural Sciences, Comenius University, Mlynská dolina, Ilkovičová 6, 942 15 Bratislava, Slovak Republic

The Upper Cretaceous – Paleocene Pupov Fm. exposed between Terchová and Zázrivá villages in the Varín (Kysuce) sector of the Pieniny Klippen Belt consists of hundreds of meters thick flysch-like sequence. Due to strong backthrusting-related deformation in the studied area, the structural position of the Pupov Fm. has not been fully understood. It was considered either as a part of the Kysuca (Pieniny) Unit (Andrusov 1938) or as the upper level of the undivided Albian to Santonian–Maastrichtian flysch succession attributed to the Manín Unit (Haško and Polák 1979), currently regarded as the Klape Unit (Potfaj et al. 2003). Alternatively, the deposits of the Pupov Fm. were considered as a part of independent sedimentary cycle discordantly overlying various Jurassic to Lower Cretaceous Klippen Belt successions (Andrusov and Scheibner 1960; Scheibner 1967). Recently, the Pupov Fm. has been tentatively interpreted as a part of post-thrusting, late syn-orogenic sedimentary sequence correlated with the Gosau Group sediments overlying deep-water deposits of the Pieniny Unit or possibly the Klape Unit (Plašienka et al. 2021).

This study presents new results of petrographic and heavy mineral analyses of the Pupov Fm. including geochemical microprobe analyses of detrital Cr-spinels, tourmalines and garnets. The studied deposits include litho-quartzose to felspatho-litho-quartzose sandstones, fine-grained conglomerates and pebbly mudstones sampled at 10 localities in the Terchová-Zázrivá area. The studied deposits contain mostly lithoclasts of low- to medium-grade metamorphic rocks, basic volcanites and carbonates. Important is the presence of abundant shallow-water carbonate lithoclasts and littoral biodetritus in the fine-grained conglomerates, inferring shallowing sedimentary cycle, a common feature repeatedly occurring in the Gosau-type basin sequences.

Impoverished heavy mineral assemblage includes ultrastable tourmaline, zircon, rutile accompanied by Cr-spinel and apatite. Garnets, exclusively of almandinic composition, are rare, except one locality from pebbly mudstone where they dominate. Cr-spinels of harzburgitic peridotite composition derived from supra-subduction zones dominate over Cr-spinels of volcanic origin. Detrital tourmalines include besides schorlitic-dravitic tourmalines also subhedral to angular distinctly zoned tourmalines of schorlitic-dravitic and magnesiofoititic to foititic compositions with fine intergrowth with quartz and tourmalines possessing magnesiofoititic-foititic cores and schorlitic-dravitic rims. The primary source for the Cr-spinels and complexly zoned tourmalines appears to be in Meliata ophiolite-bearing complexes and possibly in hydrothermal veins cutting the Gemeric crystalline basement feeding flysch deposits in the original Fatric Zliechov Basin. After the Turonian emplacement of the Fatric nappe system beyond the Tatric edge, the exotics-bearing formations of the Klape Unit formed the source of ophiolitic detritus in the foreland basins of the developing accretionary wedge.

Based on the specific structural position, age, lithological composition and impoverished heavy mineral assemblage, the Pupov Fm. might represent a part of the wedge-top Gosau-type basin system developed during the meso-Alpidic (Coniacian – Eocene) tectonic epoch.

Acknowledgement: The study was financially supported by projects APVV 17-0170 and APVV-20-0079 and from the Grant Agency for Science, Slovakia (projects VEGA 1/0435/21, 2/0013/20 and 2/0028/17).

References:

Andrusov, D. 1938. Étude Géologique de la zone des Klippes Internes des Carpathes Occidentales. IIIE Partie: Tectonique. *Rozpravy Státního geologického Ústavu ČSR* 9, 1–375.

Andrusov, D. & Scheibner, E. 1960. An outline of the present state of knowledge about the geology of the Klippen Belt between Vlára river and Tvrdošín town. *Geologický Sborník* 11, 2, 239–279.

Haško, J. & Polák, M. 1979. Explanations to the geological map of the Kysucké vrchy Hills and Kriváň part of the Malá Fatra Mts. *Geological Institute of Dionýz Štúr, Bratislava*, 145 pp.

Plašienka, D., Aubrecht, R., Bezák, V., Bielik, M., Broska, I., Bučová, J., Fekete, K., Gaži, P., Gedl, P., Golej, M., Halásová, E., Hók, J., Hrdlička, M., Jamrich, M., Józsa, Š., Klanica, R., Konečný, P., Kubiš, M., Madarás, J., Majcin, D., Marko, F., Molčan Matejová, M., Potočný, T., Schlögl, J., Soták, J., Suan, G., Šamajová, L., Šimonová, V., Teťák, F. & Vozár, J. 2021. Structure, composition and tectonic evolution of the Pieniny Klippen Belt – Central Western Carpathian contiguous zone (Kysuce and Orava regions, NW Slovakia). Monograph. *Comenius University, Bratislava*, 148 pp.

Potfaj, M., Šlepecký, T., Maglay, J., Hanzel, V., Boorová, D., Žecová, K., Kohút, M., Nagy, A., Teťák, F., Vass, B., Sandanus, M., Buček, S., Sýkora, M., Köhler, E., Fejdiová, O., Kandera, K., Samuel, O., Bubík, M. & Beleš, F. 2003. Explanation to the geological map of the Kysuce region 1: 50,000. *State Geological Institute of Dionýz Štúr*, Bratislava, 193 pp.

Scheibner, E. 1967. Karpatské pásmo bradlové. In: Maheľ, M. & Buday, T. (Eds.): *Regionálni geologie ČSSR II. Západní Karpaty. Svazek 2. ÚÚG-Academia*, Praha, pp. 304–371.

Clinoforms as paleogeographic tools: the late Neogene evolution of Lake Pannon

IMRE MAGYAR[1,2]

1 – MOL Hungarian Oil and Gas Plc., Október huszonharmadika utca 18, Budapest, Hungary; e-mail: immagyar@mol.hu

2 – ELKH-MTM-ELTE Research Group for Paleontology, Budapest, Hungary

In the Late Miocene and Pliocene, the Pannonian Basin hosted a giant brackish lake, similar to the present-day Caspian Sea. Biostratigraphic studies of the basin fill in the early 20th century suggested that the areal extent of the lake significantly changed during its long history (e.g., Halaváts 1903). A more precise reconstruction of the paleogeographical changes became available when seismic studies revealed the presence of clinothems – and clinoforms as their bounding surfaces – in the lacustrine sediment body (e.g., Pogácsás 1984; Trkulja and Kirin 1984). The lake's bed was filled by lateral accretion of sediments, producing a gradual advance of the shelf-edge from the margins towards the centre of the basin from ca. 10 to 4 Ma (Vakarcs et al. 1994; Magyar et al. 2013).

Seismic mapping of the shelf-edge and dating of some key clinoform surfaces together results in a high-resolution reconstruction of the paleogeographic evolution of the basin. The shelf-edge corresponded to the boundary between the profundal and shelfal environments; the latter was covered by a few tens of m deep water. The actual lake shore frequently changed its position both basinward and landward, depending on the climatic, tectonic and sedimentary conditions. The width of the water-covered shelf thus also changed, but most typically it was about several tens of km.

A shelf can develop only in deep water. Seismic mapping of the shelf-edge is not possible above uplifted but still submerged basement highs where deposition took place in shallow-water environment. Across such regions the reconstructed shelf-edge lines are broken, but they can be correlated on the basis of their geographical and biostratigraphic positions.

Dating of the shelf-edge clinoforms was carried out by detailed biostratigraphic and magnetostratigraphic studies on drill cores, calibrated by a few radiometric ages from volcanic ashes in various parts of the basin (for a summary see Magyar 2021).

In addition to seismic mapping and borehole data, surface outcrops are increasingly involved into the spatial and temporal reconstruction of the lake's regression (e.g., Bartha et al. 2021; Radivojević et al. 2022). As new seismic and stratigraphic data are being continuously incorporated, the paleogeographic model of the lake filling becomes more and more accurate and detailed. This ongoing paleogeographic project is unique in terms of the number of countries involved (at least 6) and the variety of data used and integrated (e.g., Magyar et al. 2019).

Acknowledgement: Many stratigraphers from different countries participated and participate in this long-term project, to whom I would like to express my thanks for their cooperation.

References:

Bartha, I.R., Botka, D., Csoma, V., Katona, L.T., Tóth, E., Magyar, I., Silye, L. & Sztanó, O. 2022. From marginal outcrops to basin interior: a new perspective on the sedimentary evolution of the eastern Pannonian Basin. *International Journal of Earth Sciences* 111, 335–357.

Halaváts, J. 1903. Die Fauna der pontischen Schichten in der Umgebung des Balatonsees. Resultate der wissenschaftlichen Erforschung des Balatonsees 1/1. *Paläontologischen Abhandlungen* 4/2, 1–80.

Magyar, I. 2021. Chronostratigraphy of clinothem-filled non-marine basins: Dating the Pannonian Stage. *Global and Planetary Change* 205, 103609.

Magyar, I., Radivojević, D., Sztanó, O., Synak, R., Ujszászi, K. & Pócsik, M. 2013. Progradation of the paleo-Danube shelf margin across the Pannonian Basin during the Late Miocene and Early Pliocene. *Global and Planetary Chang*e 103, 168–173

Magyar, I., Sztanó, O., Sebe, K., Katona, T.L., Csoma, V., Görög, Á., Tóth, E., Szuromi-Korecz, A., Šujan, M., Braucher, R., Ruszkiczay-Rüdiger, Zs., Koroknai, B., Wórum, G., Sant, K., Kelder, N. & Krijgsman, W. 2019. Towards a high-resolution chronostratigraphy and geochronology for the Pannonian Stage: Significance of the Paks cores (Central Pannonian Basin). *Földtani Közlöny* 149, 351–370.

Pogácsás, Gy. 1984. A Pannon medence neogén mélydepresszióinak szeizmikus sztratigráfiai alapvonásai. *Magyar Geofizika* 25, 151–166.

Radivojević, D., Radonjić, M., Katona, L.M, & Magyar, I. 2022. Against the tide: southeast to northwest shelf-edge progradation in the southeastern margin of Lake Pannon, Banat (Serbia and Romania). *International Journal of Earth Sciences* 111, 1551–1571.

Trkulja, N. & Kirin, Ž. 1984. Fenomen kosih refleksija na konvencionalnim seizmičkim profilima severoistočne Vojvodine. Dipping reflections on conventional seismic profiles in NE Vojvodina. *Nafta* 35, 11–19.

Vakarcs, G., Vail, P.R., Tari, G., Pogácsás, Gy., Mattick, R.E. & Szabó, A. 1994. Third-order Middle Miocene-Early Pliocene depositional sequences in the prograding delta complex of the Pannonian basin. *Tectonophysics* 240, 81–106.

The Eocene – Oligocene boundary along the northern margin of the Tatra Mts in the Central Carpathian Paleogene Basin in Poland - a problem to be solved

ELŻBIETA MACHANIEC, RENATA JACH, EWA MALATA, MACIEJ KANIA and MATEUSZ SZCZĘCH

Institute of Geological Sciences, Faculty of Geography and Geology, Jagiellonian University, Kraków, Poland; e-mail: elzbieta.machaniec@uj.edu.pl

The youngest Eocene and oldest Oligocene deposites cropping out along the northern margin of the Tatra Mts are represented mainly by two rock sequences: Eocene carbonate shallow-water deposits and Oligocene sandy-shale flysch. Transition from the carbonate platform deposits to flysch is still a matter of discussion. According to one group of views there is a continuous sedimentation (Passendorfer 1959, 1983; Kępińska 1997), while the others suggest hiatus between these two rock sequences (e.g., Sokołowski 1973; Wieczorek and Olszewska 1998; Olszewska 2009). In the southern part of the Podhale Basin a strong diachronism of the Priabonian-Rupelian deposits is also postulated (Cieszkowski et al. 2009).

Moreover, the age of the Paleogene Flysch deposits based on various groups of microfossils remains ambiguous. This results partly from resedimentation, the genetic character of deposits as well as from the impoverishment of microfossils due to the paleoenvironmental changes across the Eocene – Oligocene boundary.

At the Eocene – Oligocene boundary the global paleoenvironmental changes took place (so called Terminal Eocene Event) whose records have been studied and interpreted within the Central Carpathian Paleogene Basin (CCPB) in Slovakia (Soták 2010). Such detailed and problem-directed studies have not been performed so far in the Polish part of the CCPB. Thus, it appears to be very important to conduct extensive, high-resolution studies in the Polish part of the Podhale Basin whose results will be the base for correlation with equivalent deposits of the Slovakian part of the CCPB. Solving the assumed problems will contribute to better understanding of the CCPB basin evolution with reference to the global climatic changes.

To complete such studies and solve the problem a few sites have been selected where the Uppermost Eocene carbonate deposits have been already identified in the exposed sections. In these sections there is a great chance of an occurrence of the youngest carbonate as well as the oldest flysch deposits. For the first time high-resolution LiDAR based on the digital elevation model (DEM) was used to define the narrowest possible area for the potential location of the carbonate platform/flysch boundary (Fig. 1). Designation of such places for further detailed studies shows that the research objectives are possible to be achieved when a very high-resolution sedimentological and biostratigraphical analyses are going to be applied.

Acknowledgement: The research for this publication has been supported by a grant from the Priority Research Area (U1U/W23/NO/03.19) under the Strategic Programme Excellence Initiative at Jagiellonian University.

References:

Cieszkowski, M., Golonka, J., Krobicki, M., Ślączka, A., Oszczypko, N., Waśkowska, A. & Wendorff, M., 2009. The Northern Carpathian plate tectonic evolutionary stages and origin of olistolithes and olistostromes. *Geodinamica Acta*, 22, 1–3, 101–126.

Gedl, P. 2000. Biostratigraphy and palaeoenvironment of the Podhale Palaeogene (Inner Carpathians, Poland) in the light of palynological studies. Part I (in Polish with English summary). *Studia Geologica Polonica*, 117, 69–154.

Jach, R. & Machaniec, E. 2014. Skały eocenu. In: Jach, R., Rychliński, T. and Uchman, A. (Eds*): Skały osadowe Tatr. Tatrzański Park Narodowy − Wydawnictwa, Zakopane*, pp. 232–244.

Kępińska, B. 1997. Model geologiczno-geotermalny niecki podhalańskiej. *Studia, Rozprawy, Monografie, CPPGSMiE PAN*, Kraków, 48, 111 pp.

Olszewska, B. 2009. Small foraminifera of „Nummulitic Eocene" of the Tatra Mts. – stratigraphy and palaeoenvironment. (In Polish, English abstract). *Przegląd Geologiczny*, 57, 8, 703–713.

Olszewska, B. & Wieczorek, J. 1998. The Paleogene of the Podhale Basin (Polish Inner Carpathians) - micropaleontological perspective. *Przegląd Geologiczny*, 46, 8, 2, 721–728.

Passendorfer, E. 1958: About sedimentation of the Eocene in the Tatra. *Acta Geologica Polonica*, 8, 3, 451–475. (in Polish, English summary).

Passendorfer, E. 1983. Jak powstały Tatry. Wyd. VII, Wydawnictwo Geologiczne, Warszawa, 286 pp.

Sokołowski, S. 1959. Zdjęcie geologiczne strefy eocenu numulitowego wzdłuż brzegu Tatr Polskich. *Biuletyn Państwowego Instytutu Geologicznego*, 149, 197–213.

Soták, J. 2010. Paleoenvironmental changes across the Eocene-Oligocene boundary: insights from the Central Carpathian Paleogene Basin. *Geologica Carpathica*, 61, 5, 393–418.

Worobiec, G., Jach, R., Machaniec, E., Uchman, A. & Worobiec, E. 2015. Eocene flora and trace fossils from the Hruby Regiel section in the Tatra Mountains (Poland): taxonomic revision of the Wiktor Kuźniar fossil plant collection. *Acta Geologica Polonica*, 65, 2, 203–225.

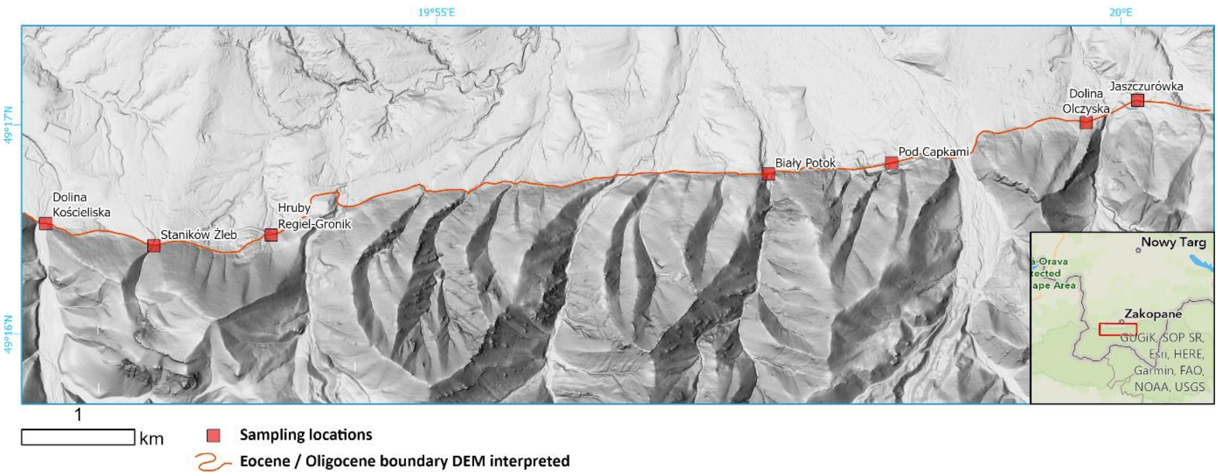


Figure 1: Location of the uppermost Priabonian deposits distinguished on the basis of large benthic and planktic foraminifera and interpretation of the Eocene – Oligocene boundary on the digital elevation model.

A new agglutinated benthic foraminifera *Remesella varians* – *Rectoprotomarssonella rugosa* Zone for the latest Maastrichtian

ELŻBIETA MACHANIEC and ALFRED UCHMAN

Jagiellonian University, Faculty of Geography and Geology, Institute of Geological Sciences, Gronostajowa 3a, 30-387 Kraków, Poland; e-mail: elzbieta.machaniec@uj.edu.pl

The Outer Carpathians are dominated by Cretaceus–Paleogene turbiditic (flysch-type) deposits that accumulated in the northern margin of the Tethys. Their biostratigraphy is based mainly on agglutinated foraminiferal zonations, precision of which is not rarely problematic. The Hyżne and Bąkowiec sections (Skole Nappe, SE Poland) offer a unique opportunity to distinguish a new biostratigraphic zone based on agglutinated foraminifera, and its correlation with standard planktonic zonations is less affected by environmental changes.

Most samples from the Upper Cretaceous turbiditic series of the Skole Nappe contain benthic agglutinated foraminifers, some of which are important for biostratigraphy. For instance, *Caudamina gigantea* and *Rzehakina inclusa* are distinctive for the Upper Cretaceous and are used as the marker taxa in some zonal schemes (Morgiel and Olszewska 1981; Geroch and Nowak 1984; Olszewska 1987; Kuhnt and Kaminski 1990; Bubík 1995). According to zonation based on benthic agglutinated taxa by Geroch and Nowak (1984), the acme Caudamina gigantea Zone indicates the upper Campanian–Maastrichtian. However, in many environments, *C. gigantea* is rare or absent throughout the Campanian and Maastrichtian (Kuhnt et al. 1989; Olszewska 1997; Waśkowska et al. 2019; Waśkowska 2021). In the sections studied, *C. gigantea* rarely occurs only in a few samples (e.g., in the Bąkowiec section, samples BK233, Bak 14A), and *Rz. inclusa* is present sporadically (e.g., in samples BK 234). According to Olszewska (1997), the acme Rzehakina inclusa Zone is based on the abundant occurrence of the index species. However, *Rz. inclusa* is a cosmopolitan (Kaminski and Gradstein 2005), uncommon species, which occurs irregularly from the late Campanian to the end of the Maastrichtian (Morgiel and Olszewska 1981; Olszewska 1997; Waśkowska et al. 2019). The stratigraphical resolution of the *C. gigantea* and *Rz. inclusa* zones is low and points to the upper Campanian–Paleocene. *Remesella varians* is used for the definition of the middle–late Maastrichtian interval in the Magura Nappe (Malata et al. 1996). Furthemore, Bąk (2004) distinguished the Remesella varians Zone for the definition of a late Maastrichtian biohorizon in the Dukla Nappe, Polish Outer Carpathians, on the basis of FO of *R. varians*. Moreover, *R. varians* characterizes the stratigraphically significant bioevent of the uppermost Maastrichtian in the North Atlantic region (Kuhnt et al. 1989), especially in the Zumaya section in Spain (Kuhnt and Kaminski 1997). Kaminski et al. (2011) dated the lower boundary of this zone to the late Campanian and the upper boundary to the late Maastrichtian in the Umbria-Marche area (Italy). *Rectoprotomarssonella rugosa* (Hanzlíková), is also stratigraphically important. Its last occurrence (LO) indicates the latest Maastrichtian, and it coincides with the K-Pg boundary (Geroch and Nowak 1984; cf. Machaniec et al. 2020). The co-occurrence of *R. varians* and *R. rugosa* allows distinguishing the concurrent range zone (CRZ) sensu Wade et al. (2011).

Remesella varians - Rectoprotomarssonella rugosa Concurrent Range Zone

Definition: The lower boundary of the Remesella varians - Retroprotomarssonella rugosa CRZ is defined by the FO of the *Remesella varians* and the upper boundary by the LO of *Rectoprotomarssonella. rugosa*. This zone embraces the interval between the FO of *R. varians* and LO of *R. rugosa* and points to the latest Maastrichtian.

Age assignment: latest Maastrichtian.

The new Remesella varians - Rectoprotomarssonella rugosa CRZ has been calibrated to standard planktic foraminiferal zonations on the basis of the Hyżne and Bąkowiec sections and bioevents of the significant stratigraphical importance (BESS) distinguished in the Hyżne section (Gasiński and Uchman 2011; Machaniec et al. 2020). It corresponds to the upper part of the Abathomphalus mayaroensis Zone (Caron 1985) and to the bioevents corresponding to the CF1 and CF2 planktic zones (Li and Keller 1998).

Occurrence: Skole Nappe, Subsilesian Nappe, Outer Carpathians, Atlantic region. Due to the fact that both species are calcareous-cemented agglutinated taxa typical of the slope marls, the R. varians - R. rugosa Zone can be applied only for deposits above the calcite compensation depth (CCD).

Remarks: In addition to the aforementioned species, other taxa typical also of the early Palaeogene are present, including *Glomospira diffundens* (Cushman and Renz), *Rzehakina epigona* (Rzehak), *Rzehakina fissistomata* (Grzybowski), *Annectina grzybowskii* (Jurkiewicz), *Hormosina velascoensis* (Cushman), *Caudammina excelsa* (Dylążanka), *Spiroplectammina spectabilis* (Grzybowski). According to Olszewska (1997), FO of *R. varians* is observed at the base of Maastrichtian and the *R. rugosa* LO is noted below the K-Pg boundary.

Conclusions: (1) The new R. varians - R. rugosa CRZ embraces the interval between the FO of *R. varians* and LO of *R. rugosa*, which defines the lower and upper boundaries of this zone and indicates the latest Maastrichtian. (2) The K-Pg boundary lies above the R. varians-R. rugosa Zone. (3) The distinction of the R. varians - R. rugosa Zone improves the stratigraphic resolution based on agglutinated foraminifera for deposits above the CCD level.

Acknowledgement: The research for this publication has been supported by a grant from the Priority Research Area (U1U/W23/NO/03.19) under the Strategic Programme Excellence Initiative at Jagiellonian University.

References

Bąk, K. 2004. Deep-water agglutinated foraminiferal changes across the Cretaceous/Tertiary and Paleocene/Eocene transitions in the deep flysch environment; eastern Outer Carpathians (planktonic Bieszczady Mts, Poland). *In*: Bubik, M. and Kaminski, M.A. (Eds): *Proceedings of the Sixth International Workshop on Agglutinated Foraminifera. Grzybowski Foundation Special Publication*, 8, 1–56.

Bubík, M. 1995. Cretaceous to Paleogene agglutinated foraminifera of the Bílé Karpaty Unit (West Carpathians, Czech Republic). In: Kaminski, M.A., Geroch, S. and Gasiński, M.A. (Eds): Proceedings of the Fourth International Workshop on Agglutinated Foraminifera, *Grzybowski Foundation Special Publication*, 3, 71–116.

Caron, M. 1985. Cretaceous planktonic foraminifera. *In*: Bolli, H.M., Saunders, J. and Perch-Nielsen, K. (Eds): *Plankton Stratigraphy*. Cambridge University Press, Cambridge, 17–86.

Gasiński, M.A. & Uchman, A. 2011. The Cretaceous–Paleogene boundary in turbiditic deposits identified to the bed: a case study from the Skole Nappe (Outer Carpathians, southern Poland). *Geologica Carpathica*, 62, 4, 333–343.

Geroch, S. & Nowak, W. 1984. Proposal of zonation for the Late Tithonian – Late Eocene, based upon arenaceous foraminifera from the outer Carpathians, Poland. *In*: Oertli, H. (Ed.): *Benthos'83; 2nd International Symposium on Benthic Foraminifera, Pau (France), April 11-15, 1983, Elf Aquitaine, ESSO REP and TOTAL CFP, Pau and Bourdeaux*, 225–239.

Kaminski, M.A. & Gradstein, F. 2005. Atlas of Paleogene cosmopolitan Deep-Water Agglutinated Foraminifera. *Grzybowski Foundation Special Publication*, 10, 1–546.

Kuhnt, W., Kaminski, M.A. & Moullade, M. 1989. Late Cretaceous deep-water agglutinated foraminiferal assemblages from the North Atlantic and its marginal seas. *Geologische Rundschau*, 78, 1121–1140.

Kuhnt, W. & Kaminski, M.A. 1997. Cenomanian to lower Eocene deep-water agglutinated Foraminifera from the Zumaya section, northern Spain. *Annales Societatis Geologorum Poloniae*, 67, 2–3, 257–270.

Li, L. & Keller, G. 1998. Maastrichtian climate, productivity and faunal turnovers in planktic foraminifera in South Atlantic DSDP sites 525 and 21. *Marine Micropaleontology*, 33, 1–2, 55–86.

Machaniec, E., Kowalczewska, O, Jugowiec, M., Gasiński, M.A. & Uchman, A. 2020. Foraminiferal and calcareous nannoplankton bioevents and changes of the Late Cretaceous–earliest Paleogene transition in the northern margin of Tethys (Hyżne section, Polish Carpathians). *Geological Quarterly*, 64, 3, 567–588.

Malata, E., Malata, T. & Oszczypko, N. 1996. Litho- and biostratigraphy of the Magura Nappe in the Eastern part of the Beskid Wyspowy Range (Polish Western Carpathians). *Annales Societatis Geologorum Poloniae*, 66, 3–4, 269–284.

Morgiel, J. & Olszewska, B. 1981. Biostratigraphy of the Polish External Carpathians based on agglutinated foraminifera. *Micropaleontology*, 27, 1, 1–30.

Olsson, R.K., Hemleben, C., Berggren, W.A. & Huber, B.T. 1999. Atlas of Paleocene planktonic foraminifera. *Smithsonian Contribution to Paleobiology*, 85, 1–252.

Olszewska, B. 1997. Foraminiferal biostratigraphy of the Polish Outer Carpathians: A record of basin geohistory. *Annales Societatis Geologorum Poloniae*, 67, 2–3, 325–337.

Wade, B.S., Pearson, P.N., Berggren, W.A. & Pälike, H. 2011. Review and revision of Cenozoic tropical planktonic foraminiferal biostratigraphy and calibration to the geomagnetic polarity and astronomical time scale. *Earth-Science Reviews*, 104, 111–142.

Waśkowska-Oliwa, A. 2008. The Paleocene assemblages of agglutinated foraminifera from deep-water basin sediments of the Carpathians (Subsilesian Unit, Poland) – biostratigraphical remarks. *Grzybowski Foundation Special Publication*, 13, 227–265.

Waśkowska, A. 2021. Agglutinated foraminiferal acmes and their role in the biostratigraphy of the Campanian–Eocene Outer Carpathians. *Geosciences* 11, 9, 367.

Waśkowska, A., Joniec, A., Kotlarczyk, J. & Siwek, P. 2019. The Late Cretaceous Fucoid Marl of the Ropianka Formation in the Kąkolówka Structure (Skole Nappe, Outer Carpathians, Poland) – lithology and foraminiferal biostratigraphy. *Annales Societatis Geologorum Poloniae*, 89, 3, 259–284.

Integrated bio-magnetostratigraphy of the Badenian reference section Ugljevik - implications for the Paratethys history

OLEG MANDIC[1], KARIN SANT[2], MĂDĂLINA-ELENA KALLANXHI[3], STJEPAN ĆORIĆ[4], DÖRTE THEOBALT[1], PATRICK GRUNERT[5], ARJAN DE LEEUW[6] and WOUT KRIJGSMAN[2]

1 – Geological-Paleontological Department, Natural History Museum, Burgring 7, 1010 Vienna, Austria; e-mail: oleg.mandic@nhm-wien.ac.at

2 – Paleomagnetic Laboratory Fort Hoofddijk, Department of Earth Sciences, Utrecht University, Budapestlaan 4, 3584 CD Utrecht, The Netherlands

3 – Department of Geology, Faculty of Biology and Geology, Babeș-Bolyai University, M. Kogălniceanu 1, 400084 Cluj-Napoca, Romania.

4 – Geological Survey of Austria, Neulinggasse 38, 1030 Vienna, Austria

5 – University of Cologne, Zülpicher Str. 49a, 50674 Köln, Germany

6 – Univ. Grenoble Alpes, Univ. Savoie Mont Blanc, CNRS, IRD, IFSTTAR, ISTerre, 38000 Grenoble, France

Central Paratethys was a large-scale Oligo-Miocene epicontinental sea located in Central and Eastern Europe. It was separated from the Mediterranean by the Alpine orogenic belt. The Paratethys progressively flooded the Pannonian back-arc basin that formed during the early to middle Miocene. Along the southern margin of the basin, the maximum extension of the Paratethys onto the flanks of the Dinarides Mountains occurred during the middle Miocene (Kováč et al. 2017).

We have studied the most complete middle Miocene (Badenian-Sarmatian) Paratethys section located at this southern margin. It comprises a >1.5 Myr long, continuous marine depositional sequence, which is highly relevant for our understanding of the interplay between global climatic and regional geodynamic perturbations in this semi-isolated epicontinental basin. The investigated record is particularly important to assess the impact of the Middle Miocene Climate Transition, the Langhian-Serravallian glacial Mi-3b event, the syn-rift climax of the Pannonian Basin and the Badenian Salinity Crisis (BSC). Moreover, we present the first high resolution age model for the regional Badenian stage based on integrated biomagnetostratigraphy. According to our age model, the marine flooding reached the area at ~14.15 Ma, during the regional Badenian stage. Open marine conditions persisted until ~12.6 Ma when the extinction of the fully marine fauna marks the beginning of the regional Sarmatian stage.

Sea-level fluctuations are reflected in the section by four transgressive regressive cycles coinciding roughly with 400-kyr-eccentricity periods. The largest sea-level fall occurred after the first cycle and corresponds to the end of the Middle Miocene Climate Transition marked by glacial event Mi-3b. Elsewhere in the Pannonian Basin, this marked drop in base-level triggered deposition of evaporites during the Badenian Salinity Crisis. At Ugljevik however, there are no evaporites and the short-term Mi-3b regression was followed by a transgression and re-establishment of deeper marine conditions at 13.76 Ma, i.e. during the earliest Serravallian. Diversified planktonic and benthic assemblages suggest fully marine conditions with a persistent connection to the Mediterranean at this time. Such conditions prevailed until the middle Serravallian (latest Badenian) when sediment input increased and coastal environments prograded seawards. The Badenian/Sarmatian boundary roughly coincided with a 400-kyr-eccentricity as well as with a 1.2-Myr obliquity minimum.

References:

Kováč, M., N. Hudáčková, E. Halásová, M. Kováčová, K. Holcová, M. Oszczypko-Clowes, K. Báldi, G. Less, A. Nagymarosy, A. Ruman, T. Klučiar, & M. Jamrich. 2017. The Central Paratethys palaeoceanography: A water circulation model based on microfossil proxies, climate, and changes of depositional environment. *Acta Geologica Slovaca*, 9, 75–114.

Mandic, O., Sant, K., Kallanxhi, M.-E., Coric, S., Theobalt, D., Grunert, P., De Leeuw, A. & Krijgsman, W. 2019. Integrated bio-magnetostratigraphy of the Badenian reference section Ugljevik in southern Pannonian Basin - implications for the Paratethys history (middle Miocene, Central Europe). *Global and Planetary Change*, 172, 374–395.

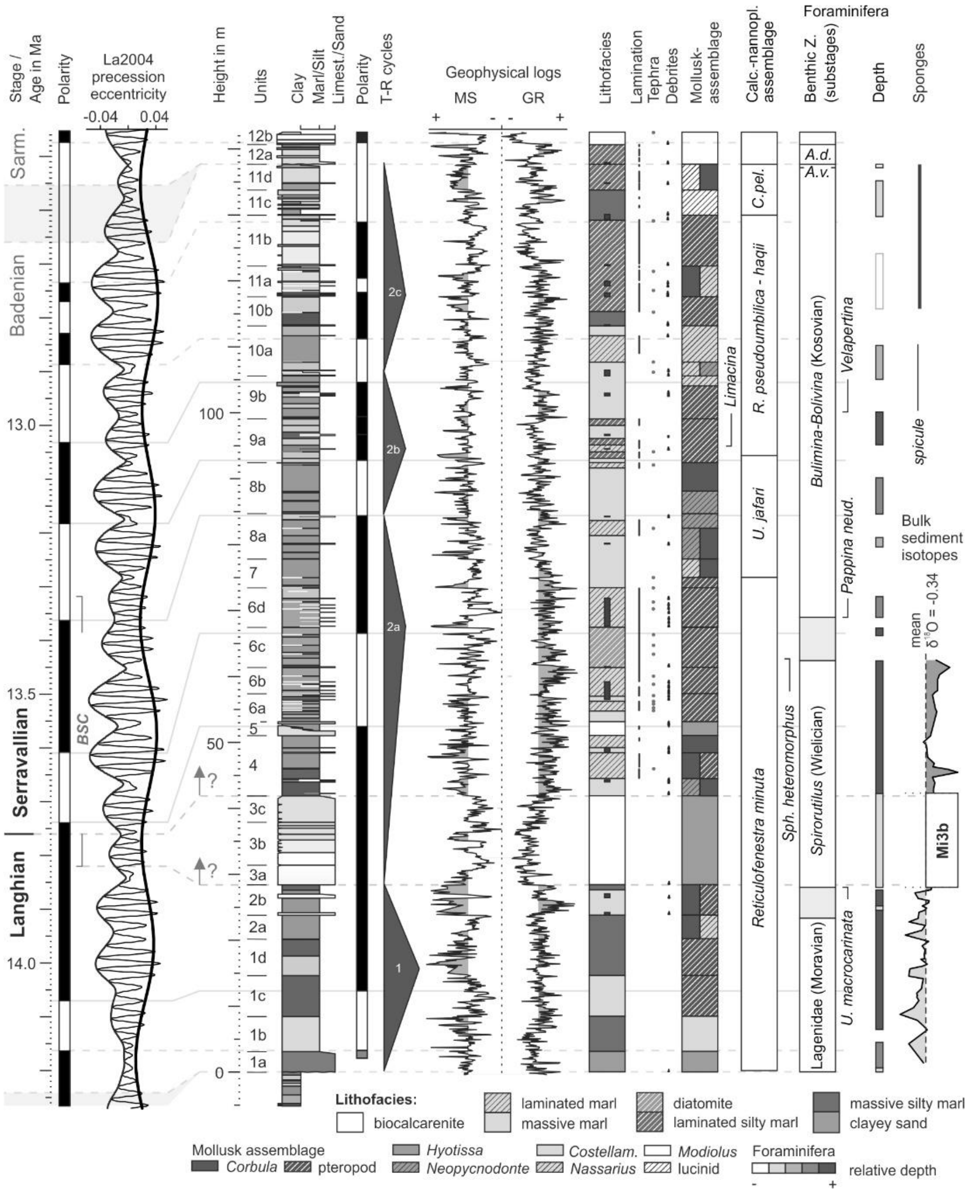


Figure 1: Integrated stratigraphy and paleoenvironment of the Ugljevik section: magnetostratigraphic correlation, lithology, Transgressive-Regressive (T-R) cycles, magnetic susceptibility (MS) and gamma ray (GR) curves, lithofacies, mollusk facies, calcareous nannofossil assemblages, ecozones based on benthic foraminiferal assemblages and $\delta^{18}O$ isotope data (from Mandic et al. 2019).

The mechanism accounting for the geometry of offshore External Dinarides

EMŐ MÁRTON[1], VLASTA ĆOSOVIĆ[2] and GÁBOR IMRE[1]

1 – Paleomagnetic Laboratory, Department of Geophysical Research, SARA, Columbus 17-23, 1145 Budapest, Hungary; e-mail: paleo@sztfh.hu

2 – Department of Geology, Faculty of Science, University of Zagreb, Horvatovac 102b, 10000 Zagreb, Croatia

The outcroping parts of offshore External Dinarides are the Adriatic islands stretching from the Kvarner islands in the NW to the Southern Adriatic islands in the SW. The chain of the islands as well as the thrust front between the External Dinarides and stable Adria have arcuated shape which is a feature easily interpreted as due to oroclinal bending.

A systematic paleomagnetic research of Cretaceous, dominantly shallow water limestones provided a substantial data set for Cres, Ist and several surrounding islets, Dugi Otok, Brač, Hvar, Korčula, Mljet and Vis islands (Márton et al. 2014, and submitted). The best quality results from these islands are covering the Albian-Santonian time interval. They document, with exceptionally precise paleomagnetic data, the lack of relative vertical axis rotation between the islands, i.e. clearly contradict the oroclinal bending as a possible mechanism accounting for the observed geometry. However, observations of the superposition of the products of Late Cretaceous (E-W compression), Late Eocene (NE-SW compression) and Neotectonic (N-S compression) strain field from Brač island (Marinčić 1997) provide a key to the arcuated shape. The structures belonging to the first are dominant in the northernmost, those related to the second, in the northern and the third in the Central and southern Adriatic island. The field measurements of the strikes of the beds sampled for the paleomagnetic studies are in line with this model. Moreover, the Albian-Santonian paleomagnetic vectors from the Adriatic islands are perfectly aligned with those for the outcoping areas (stable foreland of the Southern Alps and stable Istria), pointing to the absence of significant vertical axis rotation between them.

Acknowledgement: This work was supported by the National Development and Innovation Office of Hungary, project K 128625, and by the Croatian Scientific Foundation, Project IP 04-2019-5775 BREEMECO. We sampled in active quarries (Pučišća, Župa) thanks to M. Vlahović, mag. ing. geol. and JADRANKAMEN d.d., and Mr. Đani Nigoević from BERICA d.d. The sites from the natural protected areas were also sampled, and we would like to thank the authorities of National park Mljet and Public Institution Sea and Karst (County of Split and Dalmatia).

References:

Marinčić, S. 1997. Tectonic Structure of the Island of Hvar (Southern Croatia). *Geologica Croatica* 50/1, 57–77.

Márton, E., Ćosović, V. & Moro, A. 2014. New stepping stones, Dugi otok and Vis islands, in the systematic paleomagnetic study of the Adriatic region and their significance in evaluations of existing tectonic models. *Tectonophysics,* 611, 141–154.

Márton, E., Ćosović, V., Imre, G. & Velki M. Submitted. Changing directions of the tectonic structures, consistent paleomagnetic directions at the NE imbricated margin of Stable Adria. *Tectonophysics.*

Calpionellids on the Jurassic / Cretaceous boundary and their lorica ultrastructure

JOZEF MICHALÍK[1], SILVIYA PETROVA[2] and DIANA ÖLVECZKÁ[1]

1 – Earth Science Institute, Slovak Academy of Sciences, Dúbravská cesta 9, P.O.Box 106, 840 05 Bratislava, Slovak Republic; e-mail: geololve@savba.sk

2 – Geological Institute, Bulgarian Academy of Sciences, Acad. G. Bonchev str. 24, 1113 Sofia, Bulgaria

Fossil calpionellid loricas represent an important constituent of Tethyan subtropical microplankton of the Tethys Ocean. They are traditionally divided into “hyaline” and “chitinelloid” ones due to their ultrastructure, although detailed observations are very scarce in the literature. Transparent matter of hyaline calpionellids layer usually consists of densely arranged rhomboid crystals sometimes merging into larger aggregates and skalenoeders. They penetrate the outer lorica surface and form more-or-less distinct hexagonal pattern on it. However, regular laminar platy structure has been also observed, usually in aboral parts of lorica.

The test structure of chitinoidellids is completely different. It is formed by easily disintegrable dark matter containing dispersed calcite crystals oriented normal to the outer surface.

Age of the radiolarian assemblage from the Šariš Unit near Zázrivá (Pieniny Klippen Belt)

MARÍNA MOLČAN MATEJOVÁ and DUŠAN PLAŠIENKA

Department of Geology and Paleontology, Faculty of Natural Sciences, Comenius University, Ilkovičova 6, 841 04 Bratislava, Slovak Republic; e-mail: marina.matejova@uniba.sk

The Pieniny Klippen Belt (PKB) is an interesting, but very complex and ambiguous zone, which is formed mainly by the Oravic units - Pieniny, Subpieniny and Šariš. The Šariš Unit was only recently defined (eastern part of the PKB; Plašienka and Mikuš 2010) and till now, no attention has been paid to the study of its radiolaria-bearing formations. In previous researches the majority of localities with the occurrence of radiolarites in the PKB were assigned primarily to the Pieniny Unit, while according to current studies a substantial part of these localities belongs to the Šariš Unit. In order to identify the differences in radiolarites between individual units and to define their stratigraphic boundaries, we started the sampling of radiolarite formations of the Šariš Unit throughout several segments of the PKB. In this part of the study, the determined radiolarian assemblages come from radiolarites from outcrops (Z2, Z3, Z10) around the village of Zázrivá. Tectonically, the area belongs to the Havrania Zone of the Varín sector of the PKB (Plašienka et al. 2021). The Havrania Zone is constituted by the non-Oravic Kozinec Unit, which is formed by the Orava Series, and by the Oravic Pieniny, Subpieniny and Šariš units, the latter just recently determined in the region by Plašienka et al. (2021). The investigated ribbon radiolarites are red, partially red to grey, and grey to green-grey in colour. The outcrops are relatively small and the layers are visibly condensed with only a few meters of thickness. The presence of radiolarians in the samples is scarce, and yielded specimens are poorly preserved. The Z3 outcrop in a forest path under the Končitý vrch exposes vertically dipping radiolarites of the Czajakowa Formation together with siliceous black shales determined as the underlying Sokolica Formation (Šariš Unit) of most likely Bajocian age (possibly also Bathonian age) (Plašienka et al. 2021). Radiolarites from the locality Z10 are outcropping in the slope beneath the Z3 outcrop. Samples from both localities were very poor in radiolarians, with no determinable specimens from the Z10 outcrop. The exposure Z2 is located on the northern banks of connection of the Zázrivka and Kozinský creeks, where the red to grey radiolarites are subvertically dipping. Radiolarites from this locality yielded the richest assemblage of the sampled sites. Some of the determined radiolarians are *Acaeniotyle (?) umblicata* (RÜST), *Spinosicapsa spinosa* (OŽVOLDOVÁ), *Triactoma blakei* (PESSAGNO), *Angulobrachia (?) rugosa* JUD, *Paronaella* cf. *mulleri* PESSAGNO, *Praeconosphaera* sp., *Zhamoidellum* sp., *Praecanetta (?)* sp., *Archaeodictyomitra* sp., *Emiluvia* sp. and *Tritrabs* sp. which are assignable to the UA8 Zone (Oxfordian, possibly Late Oxfordian age). These radiolarite layers correspond with the Czajakowa Formation. Disregarding the poor preservation of radiolarians in the samples but considering the character of radiolarites (width of the formation) and the lithostratigraphic and structural affiliation of surrounding formations, we interpret the radiolarites as belonging to the Šariš Unit.

Acknowledgement: The authors express their gratitude to the financial support from the scientific projects APVV-17-0170 and VEGA 1/0435/21.

References:

Plašienka D. & Mikuš V. 2010: Geological setting of the Pieniny and Šariš sectors of the Klippen Belt between Litmanová and Drienica villages in the eastern Slovakia. *Mineralia Slovaca*, 42, 2, 155–178.

Plašienka D., Aubrecht R., Bezák V., Bielik M., Broska I., Bučová J., Gaži P., Gedl P., Halásová E., Hók J., Jamrich M., Józsa Š., Klanica R., Konečný P., Kubiš M., Madarás J., Marko F., Majcin D., Molčan Matejová M., Schlögl J., Soták J., Šamajová L., Šimonová V. & Vozár J. 2021: Structure, composition and tectonic evolution of the Pieniny Klippen Belt – Central Western Carpathians contiguous zone (Kysuce and Orava regions, NW Slovakia). *Comenius University*, *Bratislava*, 1–148.

Opening and closure of the Penninic ocean basin at the Alpine-Carpathian transition: new structural data and U-Pb zircon ages

FRANZ NEUBAUER[1], XIAOMING LIU[2], YUNPENG DONG[2], SHUYUN CAO[1,3] and ISABELLA MERSCHDORF[1]

1 – Dept. of Environment and Biodiversity, University of Salzburg, Hellbrunner Str. 34, A-5020 Salzburg, Austria; e-mail: franz.neubauer@plus.ac.at

2 – State Laboratory of Continental Dynamics, Department of Geology, Northwest University, Northern Taibai Str. 229, Xi'an 710069, China

3 – State Key Laboratory of Geological Processes and Mineral Resources, School of Earth Sciences, China University of Geosciences, Wuhan 430074, China

Ophiolites play a key role in recognition of sutures within mountain belts. This is particularly true for the Alpine orogenic belt, in which the term ophiolite was coined. In Alps, however, ophiolite formation has been poorly correlated with formation of adjacent passive margins, and uncertainties in mode of rifting, symmetric vs. asymmetric, and timing of passive margin formation and oceanic spreading exist. The Rechnitz window group of the Eastern Alps exposes Penninic Mesozoic oceanic and metasedimentary syn- and post-rift continental margin successions along the South Burgenland basement High, which is part of the Bohemian Spur, an inherited crustal-scale structure at the transition of Alps to Carpathians and Pannonian Basin. Based on re-evaluation of the structure and stratigraphy of metamorphosed ophiolitic and adjacent passive margin successions, new U-Pb zircon ages from a metamorphosed plagiogranite and detrital syn-rift sediments, the tectonic history, the mode of opening and closure of Penninic units is reinterpreted.

In the Rechnitz window group, two tectonic units are distinguished, the Schlaining unit with ophiolites, which show a Paleogene history of subduction, and the structurally underlying Kösczeg unit with distal passive continental margin successions indicated by their richness of continent-derived siliciclastic material. A blueschist with a plagiogranite protolith of the Schlaining unit yields a weighted mean zircon $^{206}Pb/^{238}U$ age of 142.5 ± 2.8 Ma (earliest Cretaceous) interpreted to represent the age of oceanic spreading. The age is younger than the 166 to 148 Ma-ages of the ophiolites in the main Piemontais-Ligurian oceanic basin and older than the ca. 95 to 90 Ma-ages of the Valais basin. This new age, however, is consistent with the age of the syn-rift phase and subsidence of halfgraben on tilted blocks during Doggerian and Malmian in the east of the Bohemian Spur.

Detrital zircons of three samples from quartzitic rocks from the underlying Köszeg unit show a wide variety of U-Pb age populations and significant differences between the three samples suggesting heterogeneous sources. Single grain ages range from 215 to 2860 Ma, with some small peaks at 440, 600, 670, 1010, 1400, 2000 and 2500 Ma. Whereas one sample is dominated by Variscan ages, ca. 325 Ma, another sample is dominated by Panafrican age groups at 600 and 670 Ma. We interpret this heterogeneity and the different sources to derive from a rift shoulder, which shows either (Model 1) a lateral transition from Variscan granites (with ages at ca. 325 Ma) to Panafrican sources (500 – 670 Ma), or (Model 2) from two different passive margins during the rift stage. The presence of Permian and rare Triassic ages indicates the significance of Austroalpine and/or Southalpine sources. In Model 1, the lateral transition from Variscan to Panafrican sources potentially correlate with the Moldanubian-Brunia transition along the Jurassic stable European continent in the northwest. The alternative, more likely Model 2 implies derivation of dominant Variscan sources from the north, and derivation of Panafrican and subordinate Triassic zircons from Austroalpine sources in the southeast.

Acknowledgement: We appreciate discussions with many colleagues including Harry Fritz and Johann Genser. We acknowledge partial support by the Austrian Science Fund, grant no. M-1343 to SC.

References:

Chang, R.H., Neubauer, F., Liu, Y.J., Yuan, S.H., Genser, J., Huang, Q.W., Guan, Q.B. & Yi, S.Y., 2021. Hf isotopic constraints for the Austroalpine basement evolution of Eastern Alps: review and new data. *Earth Science Reviews*, 221, 103772.

Friedl, G., Cooke, R.A., Finger, F., McNaughton, N.J. & Fletcher, I.R. 2011. Timing of Variscan HP-HT metamorphism in the Moldanubian Zone of the Bohemian Massif: U-Pb SHRIMP dating on multiply zoned zircons from a granulite from the Dunkelsteiner Wald Massif, Lower Austria. *Mineralogy and Petrology*, 102, 63–75.

Kohút, M., Linnemann, U., Hofmann, M., Gärtner, A. & Zieger, J. 2022. Provenance and detrital zircon study of the Tatric Unit basement (Western Carpathians, Slovakia). *International Journal of Earth Sciences*, 111, 2149–2168.

Neubauer, F., Liu, Y.J., Dong, Y.P., Chang, R. H., Genser, J. & Yuan, S. H., 2022. Pre-Alpine tectonic evolution of the Eastern Alps: From Prototethys to Paleotethys. *Earth-Science Reviews*, 226, 103923.

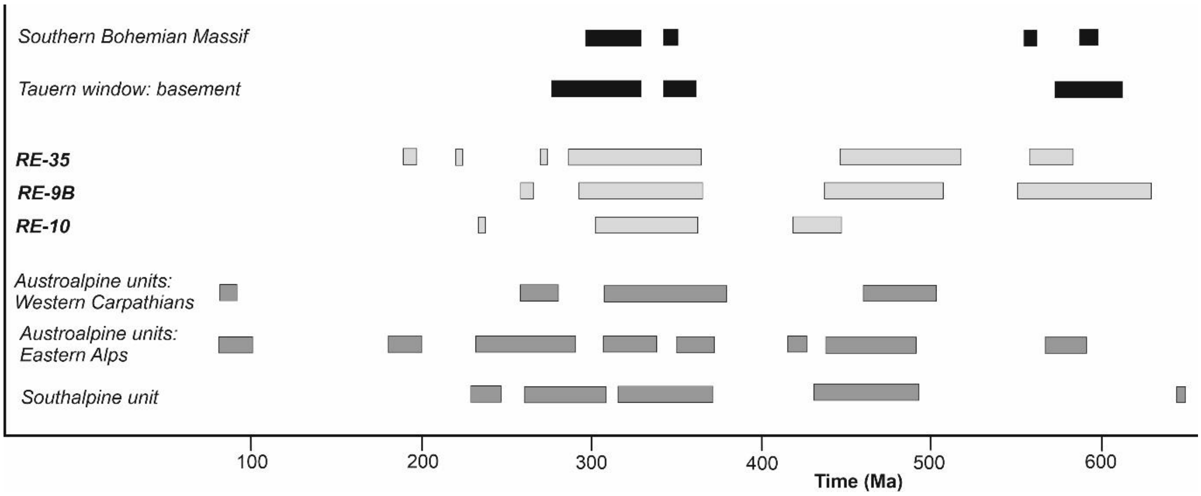


Figure 1: Range of U-Pb zircon ages of the continental units assumed to have bordered the Piemontains-Ligurian Ocean and age ranges of investigated detrital zircons. Data sources for Austroalpine and Southalpine units: Chang et al. (2021), Friedl et al. (2011), Kohút et al., (2022), Neubauer et al. (2022) and further published papers.

Reinterpretation of the Outer Carpathian paleogeography based on the study of the exotic blocks from the turbidite series

MARIUSZ PASZKOWSKI, ROBERT ANCZKIEWICZ, PRZEMYSŁAW GEDL, ARTUR KĘDZIOR, STANISŁAW MAZUR and MATEUSZ MIKOŁAJCZAK

Instytut Nauk Geologicznych Polskiej Akademii Nauk, ul. Twarda 51/55, 00-818 Warszawa; e-mail: ndpaszko@cyfronet.pl

The provenance of sedimentary rocks nowadays is most commonly examined by geochronology of heavy accessory minerals like zircons, monazite or apatite and/or bulk rock geochemical analyses. Additional mean is provided by large rock fragments transported in fine grained matrix, often termed as exotic blocks. Since they are little affected by the disintegration process they provide deeper insight into the nature of the crust forming the source region and offer more precise provenance determination. We collected a large set of the exotics derived from all major tectono-sedimentary units forming the Western Outer Carpathians and subjected them to petrographic and geochronological studies. Our results enabled us to propose a novel paleogeographic reconstruction of the source areas for the Western Outer Carpathian flysch strongly contrasting with the long-standing classical model, dating back to the first half of the last century.

The fundamental role in the classical model play the so called "cordilleras", understood as eroded ridges separating individual sub-basins. In our view, their presence is unnecessary to explain the provenance of siliciclastic detritus filling the sub-basins. Consequently, identifying the infills of individual sub-basins and correlation with the structural units of the Carpathian orogen requires a major revision. The provenance domains distinguished by us reflect the diversified tectonostratigraphic structure of the source areas and are manifested by a different inventory of exotics. Our evolutionary basin scenario involved two major stages. The first, Cretaceous-Palaeogene stage, occurred on a passive continental margin, as indicated, inter alia, by the nature of the detritus derived mainly from the areas of the pre-Alpine consolidation. The observed fundamental differences in the inventory of the exotics cannot be explain in the presence of a presumed common source correlated with a narrow Silesian ridge subdividing the basin. The Istebna Beds of the Silesian basin, commonly believed to originate from erosion of the northern slope of the Silesian Cordillera contain exotics characteristic of the source area located within the marginal part of the basin formed by the Moravian-Silesian Variscan externides and their Cadomian basement. The second evolutionary stage took place in the Oligocene-Miocene during deposition of the Krosno beds and is characterised by the diachronic encroachment of synorogenic clastic material into the Outer Carpathian sub-basins. The composition of the exotics suggests two major sources. One group comes from the reactivated pre-Alpine basement, whereas the other is related to the recycling of material from the Alpine accretionary prism. Based on our research, the affiliation of some turbidite sequences to sub-basins / structural units has been revised. In particular, the exposed deposits of the Skole sub-basin as well as the outermost Ukrainian Boryslav-Pokuttia unit and its counterparts extend westwards as far as the Moravian-Silesian Carpathians (Czech Republic) and have also been found in a number of tectonic windows within the Silesian Nappe west of the Dunajec River (particularly in the Skrzydlna region).

3D geological model of the bauxite-bearing district Bnižnica (Posušje, BiH): A powerfull tool from 3D visualization of geological structures to geological prospecting

IVICA PAVIČIĆ, IVAN DRAGIČEVIĆ, IDA PAVLIN,
FILIP ŠEGOVIĆ and VLADISLAV BRKIĆ

Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Pierottijeva, 6, 10 000 Zagreb, Croatia; e-mail: ivica.pavicic@rgn.hr

Bauxite deposits formed during the terrestrial phase between the Upper Cretaceous and Paleogene periods represent the most valuable bauxites economically in the Adriatic Carbonate Platform (AdCP) area. The deposits formed during Upper Cretaceous-Paleogene emersion are present on the entire AdCP. One of the largest and most exploited area is the Posušje bauxite-bearing area in western Herzegovina. Geological exploration and exploitation were very intensive between 1950 and 1990, but after that time, exploration was terminated by war events. This work aimed to collect all available data, systematize them into a 3D geodatabase and construct a 3D geological model of Snižnica, one of the most complex districts in the Posušje bauxite-bearing area. The results of this work are a composite geological map, 15 geological sections, and a 3D geological model with structural-kinematic analyses in a 3D environment and 3D bauxite prospection. The structural-kinematic analyses include fault movement analyses, the thickness of Paleogene deposits, which is important for drilling planning, reconstruction of eroded part of the Paleogene deposits in the hanging wall, spatial analysis of bauxite deposit locations, and azimuth and dip angle distribution of the palaeorelief surface. The results indicate that displacements on individual faults range between 0 and 100 m, while the maximum cumulative displacement is estimated to be ≥ 250 m (Pavlin and Šegović 2022). The thickness of Paleogene deposits ranges from 0 to almost 200 m, while the thickness of the eroded part of Paleogene deposits reaches up to 100 m (Pavlin and Šegović 2022). Maps of azimuth and dip angle distribution of the palaeorelief surface and analysis of structural positions of bauxite deposits indicate that a larger number of deposits are in the anticline and syncline hinge zones, which indicates that the depressions in the palaeorelief are partly structurally predisposed (Pavlin and Šegović 2022). The constructed 3D geological model and the conducted analysis can serve as a basis for planning further exploration works, primarily drilling holes to find new bauxite deposits.

References:

Pavlin I. & Šegović, F. 2022. Geološki model boksitonosnog područja Snižnice (Posušje, Bosnia and Herzegovina): pronalazak novih ležišta boksita pomoću 3D/2D vizualizacija geološke građe podzemlja. *Rectors award paper, Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Croatia*.

From valley to valley – heterochronous paleoclimatic and paleoecologic evolution of the Tatra Mts. as inferred from lacustrine deposits

RADOVAN PIPÍK[1], DUŠAN STAREK[2], RASTISLAV MILOVSKÝ[1], JURAJ ŠURKA[1], PETER UHLÍK[3], STANISLAVA MILOVSKÁ[1], MARINA VIDHYA[1], LUCIA ŽATKOVÁ[1], RAMACHANDRAN DHAVAMANI[1], ROBERTA PROKEŠOVÁ[4], TÍMEA CHAMUTIOVÁ[5], LADISLAV HAMERLÍK[5,6] and PETER BITUŠÍK[5]

1 – Earth Science Institute, Slovak Academy of Sciences, Ďumbierska 1, 97401 Banská Bystrica, Slovak Republic; e-mail: pipik@savbb.sk

2 – Earth Science Institute, Slovak Academy of Sciences, Dúbravská cesta 9, 84005 Bratislava, Slovak Republic

3 – Department of Mineralogy, Petrology and Economic Geology, Faculty of Natural Sciences, Comenius University in Bratislava, Mlynská dolina, Ilkovičova 6, SK-842 15, Bratislava, Slovak Republic

4 – Institute of Geography, Slovak Academy of Sciences, Štefánikova 49, 814 73, Bratislava Banská Bystrica, Slovak Republic

5 – Matej Bel University, Department of Biology and Ecology, Tajovského 40, SK-97401 Banská Bystrica, Slovak Republic

6 – Institute of Zoology, Slovak Academy of Sciences, Dúbravská cesta 9, 84005 Bratislava, Slovak Republic

A paleolimnological investigation of eleven lakes of glacial origin located on the Slovak side of the Tatra Mts. explored the high facial variability of the limnic infill and variable extrinsic factors that affected a postglacial deposition and changed past ecological conditions of some lakes. The oldest limnic deposits found only in four lakes were varved sediments that have been forming under glacial/proglacial conditions since ~17,700 cal yr BP.

These varves sedimented in cold, oxygen-rich, ultra-oligotrophic, slightly acidic conditions and were dominated by a species-pour chironomid community composed of cold stenothermal taxa, such as *Pseudodiamesa nivosa* and *Micropsectra radialis*-type. The diatom community is also species poor and it indicates release of nutrients from glacial ice.

The termination of this type of deposition is heterochronous among the lakes with the youngest varves being dated to ~9,800 cal yr BP. This indicates that the last glacier in the Tatra Mts. disappeared in the Early Holocene and that the deglaciation process was driven not only by global climatic conditions but also by local ones, related to terrain attributes (e.g., altitude and orientation of valleys). Once the valleys were ice-free, varve production ceased and a period of homogenous or irregularly laminated silt deposition started. The thickness of this facies is variable and occasionally reaches up to 30 cm. The facies formed probably under paraglacial conditions and is characterized by the appearance of acidophilous and oligotrophic-mesotrophic diatom communities.

This deposition terminated suddenly or continually shifted to organic one (gyttja). Change from clastic to organic deposition with dispersed clayey to sandy grains is connected to the appearance of less cold-restricted chironomids and diatom communities with wider trophic tolerance and circumneutral to alkaliphilous conditions. The oldest gyttja was dated back to ~13,800 cal yr BP, but beginning of organic deposition depends on the termination of glacial/paraglacial conditions in the valley and other extrinsic factors. Leakage of the morainic dam could cause the initiation of organic deposition in Velické pleso 3,470 cal yr BP ago and a fault activity and/or change in the hydrological regime have likely induced the change from fine clastic to humic organic deposition in Nižné Rakytovské pleso around 3,700 cal yr BP.

The gyttja is intercalated by mm, occasionally up to dm thick intervals with silty and sandy laminae as a result of the short-lasting fluvial or mass movement processes. Each lake has its own clastic input periods reflecting more the local rock mechanic properties and distance from the tributary mouth than periods of the Holocene climatic variability (Klapyta et al. 2016).

Acknowledgement: This work was financially supported by the projects APVV-15-0292 and VEGA2/0163/21.

References:

Klapyta, P., Zasadni, J., Pociask-Karteczka, J., Gajda, A. & Franczak, P. 2016. Late Glacial and Holocene Paleoenvironmental records in the Tatra Mountains, East-Central Europe, based on lake, peat bog and colluvial sedimentary data: A summary review. *Quaternary International*, 415, 126–144.

Evolution of the Dreveník and the Spiš Castle travertine plateaus in Slovakia (Late Pliocene to Holocene)

DANIEL PIVKO

Department of Geology and Paleontology, Faculty of Natural Sciences, Comenius University, Bratislava, Slovak Republic; e-mail:Daniel.pivko@uniba.sk

The current triangular remnant of the Dreveník plateau exceeds 1 km2 in size, what represents the largest travertine accumulation in Slovakia. A much smaller oval remnant of the Spiš Castle plateau is situated close by. Structural measurements in many quarries and travertine walls, lidar-derived images, research reports and historical maps have enabled a reconstruction of individual spring mounds and fissure ridges inside plateau remnants.

1. The Late Pliocene (3.6 – 2.6 Ma) spring mounds were formed on undulated Paleogene flysch sediments during the warm climate period. Travertine forms were developed with smooth slope cascades with overlying prograding lobes, indicated by the angular unconformities. Cream coloured bedded travertine with white patina is composed of crystalline crust alternated with microphyte travertine. Crystalline crusts consist especially of fan- to feather-like crystals. Macroporous microphyte travertine is built of cyanobacteria and algae mats and crusts. Individual mounds aligned to coalesced mounds in the form of the Spiš Castle and the Dreveník plateaus about 60 m in thickness and at least 2x1 km. Brittle plateaus were during the ongoing travertine deposition cut through by a system of joints and fissures due to the plastic flysch substrate. The fissures became a place of mineral water discharge with a formation of subvertical veins and fissure ridges. The geomorphological forms and depositional facies of the Dreveník and the Spiš Castle travertines are similar to the forms and facies in Rapolano Terme (Italy) and Mammoth Hot Springs (USA).

2. During the Pleistocene and the Holocene, the brittle deformation connected with weathering, karstification and erosion formed fissure systems especially parallel to plateau margins. Significant cambering built steep marginal rock walls (up to 40 m high), rock towns (Kamenný raj), gorges (Peklo), and finally block fields. Large parts of original mound and ridges were destroyed during 3 Ma. Deep fissures became vertical caves with brown speleothems.

3. Some marginal parts of travertine plateaus, rock towns and block fields have been worked-out since the 12th century for lime and building stone. The largest extraction occurred in the 20th century.

Acknowledgement: This research was supported by the contract APVV 20-0079 and VEGA 2/0013/20.

References:

Brogi, A., Capezzuoli, E., Karabacak, V., Alcicek, M.C. & Luo, L. 2021. Fissure Ridges: A Reappraisal of Faulting and Travertine Deposition (Travitonics). *Geosciences MDPI*, 11, 278, 1–25.

De Filippis, L. & Billi, A. 2012. Morphotectonics of fissure ridge travertines from geothermal areas of Mammoth Hot Springs (Wyoming) and Bridgeport (California). *Tectonophysics*, 548–549, 34–48.

Gradziński, M., Wróblewski, W., Duliński, M. & Hercman, H. 2014. Earthquake-affected development of a travertine ridge. *Sedimentology*, 61, 1, 238–263.

Guo, L. & Riding, R. 1998. Hot-spring travertine facies and sequences, Late Pleistocene, Rapolano Terme, Italy. *Sedimentology*, 45, 163–180.

Pivko, D. 2021. A review of Slovak travertine and tufa facies and their environment. *Acta Geologica Slovaca*, 13, 2, 129–166.

Pivko, D. & Vojtko, R. 2021. A review of travertines and tufas in Slovakia: geomorphology, environments, tectonic pattern, and age distribution. *Acta Geologica Slovaca*, 13, 1, 49–78.

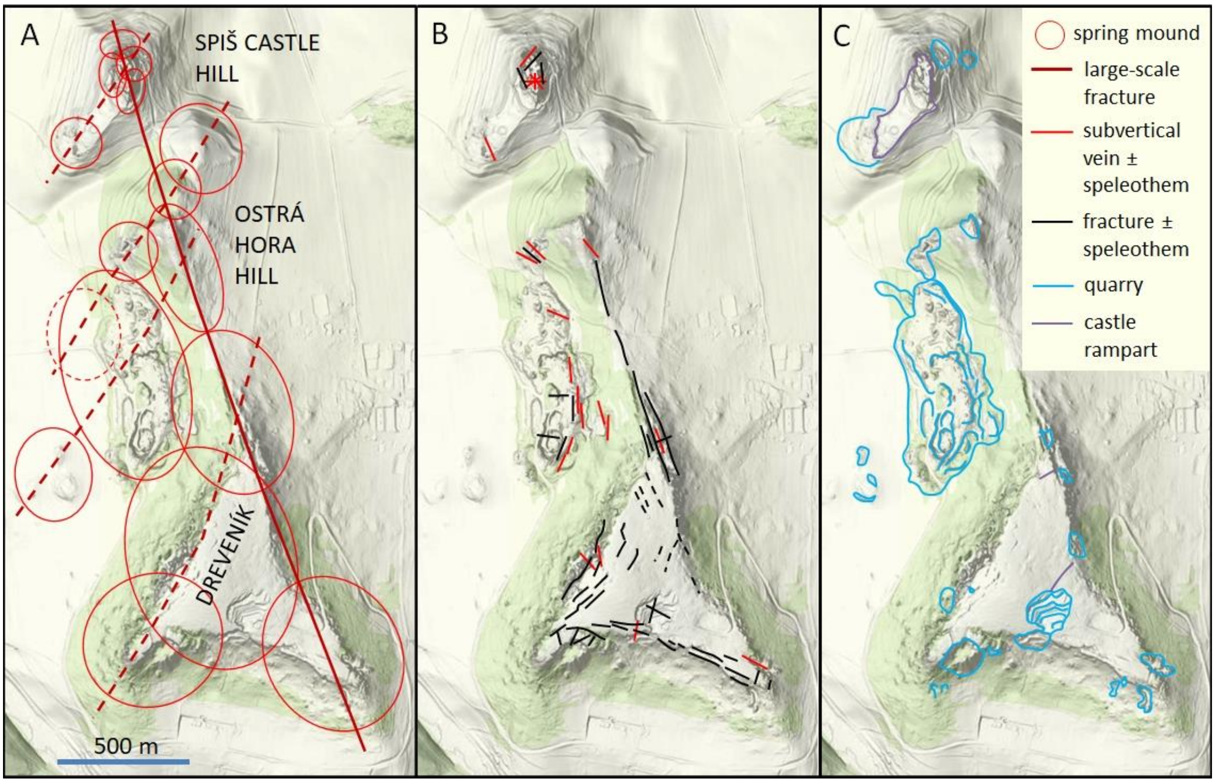


Figure 1: Lidar-derived images of the Spiš and the Dreveník plateaus. A – individual spring mounds, B – syn-sedimentary veins and post-depositional fractures, and C – human activity.

Structure of the Čergov segment of the Western Carpathian Klippen Belt (north-eastern Slovakia)

DUŠAN PLAŠIENKA[1], PRZEMYSŁAW GEDL[2], ŠTEFAN JÓZSA[1], JÁN SOTÁK[3] and MARÍNA MOLČAN MATEJOVÁ[1]

1 – Department of Geology and Palaeontology, Faculty of Natural Sciences, Comenius University, Ilkovičova 6, 842 15 Bratislava, Slovak Republic; e-mail: dusan.plasienka@uniba.sk

2 – Institute of Geological Sciences, Polish Academy of Science, Research Centre in Kraków, Senacka 1, 31-002 Kraków, Poland

3 – Earth Science Institute of the Slovak Academy of Sciences, Geology Division, Dúbravská cesta 9, P.O.BOX 106, 840 05 Bratislava, Slovak Republic

An outstanding Carpathian structure, the Pieniny Klippen Belt (PKB), spreads as a very narrow zone for some 600 km separating the Cretaceous stack of the Austroalpine basement and cover nappes of the Central Western Carpathians and the Cenozoic accretionary wedge of the External Carpathians (Flysch Belt). Due to the important along-strike diversities, several laterally connected PKB segments can be discerned. One of them, about 25 km long Čergov sector in NE Slovakia, is unique by its composition, structure and landscape. It might serve as an etalon of early tectonic history of the PKB, since the original nappe structure of Oravic units is well preserved there, regardless of significant post-nappe deformation. We present some new biostratigraphic and structural data, in particular from the Šariš Unit, which shed more light on the palaeogeographic and palaeotectonic evolution of the PKB as a whole.

The Oravic nappe system consists of three main units – the lowermost Šariš Unit juxtaposes the Magura Unit to the north and is overridden by the Subpieniny Unit composed of several successions derived from the Czorsztyn Ridge and its slopes. The uppermost Pieniny Nappe is the largest unit in area of the western part of the Čergov sector, but it rapidly wedges out eastwards. On the other hand, the Šariš Unit widens and becomes the only PKB unit building the eastern part. The Subpieniny Unit (Czorsztyn and related "transitional" successions) appears only in narrow stripes and lenses in between.

The stratigraphic succession of the Šariš Unit is all but complete, ranging from the upper Early Jurassic up to Paleocene–Early Eocene. However, only fragments of Jurassic to Lower Cretaceous successions are occasionally exposed, whereas the area is dominated by the Upper Cretaceous and Paleocene formations. The former occur in narrow and internally tightly imbricated lenticular antiforms. Examples include e.g. narrow ravines NE of Kyjov village (Szlachtowa, Opaleniec, Sokolica, Czajakowa, Palenica, Pieniny and Malinowa fms) and NE of Milpoš village (Czajakowa, Pieniny, Kapuśnica, Wronine, Hulina and Malinowa fms). The Upper Cretaceous Malinowa Fm. is exceptionally up to several hundred metres thick complex of variegated, mostly cherry-red, calcite-free shales and greenish-grey, siliciclastic turbiditic sandstones that form also massive, tens of metres thick bodies near Ľutina village. All these formations have been stratigraphically determined based of organic-walled dinoflagellate cysts, foraminifers and radiolarians.

The more than 1 km thick calcareous flysch complex of the Maastrichtian–Lower Eocene Jarmuta-Proč Fm. deserves a special attention due to the presence of huge bodies of limestone olistostromes named the Milpoš Breccia (Plašienka and Mikuš 2010). The breccias carry megaolistoliths hundreds of metres in diameter derived from the overlying Subpieniny Unit (Middle Jurassic to Lower Cretaceous limestones and radiolarites of the Czorsztyn and/or Niedzica and Czertezik successions) – for instance klippen of Sokol near Kyjov, Predné skálie, Kamenica Castle cliff, Milpoš, or Hanigovce Castle rock. Some of these klippen are composite bodies involving slices of several different successions, such as Zadné skálie or Lysá hora between Kyjov and Kamenica. We consider them as slide blocks torn off the frontal parts of the overriding Subpieniny Nappe. As such, they correspond to an intermediate stage between the compression-driven thrusting and the gravity-driven downslope movement of released fragments of the thrust body.

Relying on the sedimentary, stratigraphic and structural records, the tectonic evolution of the eastern PKB branch can be tentatively partitioned into several stages (Plašienka et al. 2020 and references therein): 1) Lower – early Middle Jurassic pre-orogenic rifting documented by the syn-rift clastic formations; 2) Bajocian rifting climax, breakup of the Váh Ocean and origin of the Czorsztyn Ridge; 3) late Middle Jurassic to Late Cretaceous post-rift thermal subsidence with bathyal to abyssal pelagic deposition, partly below CCD; 4) early Senonian episode of clastic sedimentation in the Pieniny Basin with material resedimented from mid-Cretaceous wildflysch complexes of then thrusting Fatric units; 5) Maastrichtian commencement of compressional movements recorded by turbiditic sedimentation in the Subpieniny area that continued until Early Eocene in the Šariš basin; 6) sequential stacking of Oravic units during the Paleocene to Early–Middle Eocene; 7) Late Eocene dextral transpression and shaping the PKB boundaries; 8) overall Oligocene subsidence; 9) Early Miocene backthrusting; 10) general CCW rotation by some 50° during the Middle Miocene.

Acknowledgement: The authors appreciate financial support from the Slovak Research and Development Agency (projects APVV-17-170 and APVV-20-0079) and from the Grant Agency for Science, Slovakia (projects 2/0013/20 and 1/0435/21).

References:

Plašienka D. & Mikuš M. 2010. Geological structure of the Pieniny and Šariš sectors of the Klippen Belt between the Litmanová and Drienica villages in eastern Slovakia. *Mineralia Slovaca*, 42, 155–178.

Plašienka D., Bučová J. & Šimonová V. 2020. Variable structural styles and tectonic evolution of an ancient backstop boundary – the Pieniny Klippen Belt of the Western Carpathians. *International Journal of Earth Sciences*, 109, 4, 1355–1376.

Pieniny Klippen Belt in the reference to the gravity image of the Outer and Inner Carpathians

SLAWOMIR PORZUCEK and MONIKA LOJ

Department of Geophysics, Faculty of Geology, Geophysics and Environmental Protection, 30 Mickiewicz Ave., 32-050 Krakow, Poland; e-mail: porzucek@agh.edu.pl

As is well known, Pieniny Klippen Belt (PKB) is a tectonic unit located between Outer and Inner Carpathians. Compared to both large surface units, PKB is a structure of considerable length (about 600 km), but relatively narrow (from several hundred meters to 20 km) (Birkenmajer 1977). It is interesting how the PKB is visible in gravity research, which are based on the distribution of bulk density in the rock mass. A 60-kilometer fragment of PKB was selected (from Czarny Dunajec to Szczawnica) for the analysis and its width was variable from 1.5 km to 3.5 km.

Changes in the density distribution of the rock mass are analysed on the basis of the distribution of Bouguer anomaly. Bouguer anomalies were calculated not for the medium Earth crust density (2.67 $g \cdot cm^3$), but for the density of the flysch 2.5 $g \cdot cm^3$. At the distribution of Bouguer anomaly, we can notice the decrease in the value of the anomalies in the south, in the area of Outer Carpathians. These anomalies reach a minimum in the area of Orava and Nowy Targ depression and then in the area of Inner Carpathians their value began to increase. The structure of PKB is practically invisible at the distribution of the Bouguer anomalies.

In order to obtain more detailed information, a regional trend from Bouguer anomaly was removed using one of the frequency filtration methods allowing mathematical approximation of the local gravity anomalies. The upward continuation up to a height of 3,000 m allowed to obtain a distribution of residual anomalies. On the distribution of the residual anomalies, the gravity effect is best visible from lighter rocks that build Orava–Nowy Targ Basin. There was also a negative anomaly in the Ochotnica Dolna area in the Magura Unit. Another negative anomaly is marked on the NW from its, between Kamienica and Łącko. Both of these anomalies testify to the reduced average bulk density in their area. Based on the distribution of the residual anomalies, we can see the northern PKB border, which coincides with the southern border of the Nowy Targ depression. However, the southern PKB border is still invisible.

This was the reason why the further interpretation of gravity data was based on methods that allow the separation of linear structures, using derivatives of gravity. In the interpretation were used analytic signal (Hidalgo-Gato and Barbosa 2015) and total horizontal derivative (Cooper and Cowan 2011). Both methods are used to locate disturbing body boundaries, which are also density boundaries. The interpreted boundaries of both depressions are well in line with those defined from geological surveys, and therefore the northern boundary of PKB is also clearly visible. It also stands out east of depression. In contrast, the southern boundary is almost invisible, but the density boundary inside the belt has become apparent.

The use of several methods of gravity interpretation allowed to determine the boundaries of the Pieniny Klippen Belt, which proved that this method can be effective in searching for such boundaries, as well as confirming their existence on the basis of geological premises. The inability to trace the southern boundary indicates the lack of contrast of average density between the rocks of Pieniny Klippen Belt and the Podhale Paleogene.

References:

Birkenmajer, K. 1977. Jurassic and Cretaceous lithostratigraphic units of the Pieniny Klippen Belt, Carpathians, Poland. *Studia Geologica Polonica*, 45, 2, 1–159.

Cooper, G.R.J. & Cowan D.R. 2011. A generalized derivative operator for potential field data. *Geophysicsal Prospecting*, 59, 188–194.

Hidalgo-Gato, M.C. & Barbosa, V.C.F. 2015. Edge detection of potential-field sources using scale-space monogenic signal: Fundamental principles. *Geophysics, 80, 5, J27–J36*.

Metarhyolites of Meliatic Bôrka Nappe: Zircon U-Pb LA-ICP-MS dating of Triassic volcanism, Western Carpathians, Slovakia

TOMÁŠ POTOČNÝ[1], MARIÁN PUTIŠ[2] and JIŘÍ SLÁMA[3]

1 – Department of Geology and Paleontology, Comenius University Bratislava, Ilkovičova 6, Bratislava, Slovak Republic; e-mail: potocny9@uniba.sk

2 – Department of Mineralogy, Petrology and Economic Geology, Comenius University Bratislava, Ilkovičova 6, Bratislava, Slovak Republic

3 – Department of Geological Processes, Institute of Geology of the Czech Academy of Sciences, Rozvojová 269, Praha, Czech Republic

The Meliata Unit in current geological structure of the Western Carpathians represents limited relics of the mid-Triassic-Jurassic Meliata(-Hallstatt) Ocean (Mock et al. 1998). These fragments occur in limited tectonic windows and slices in the Spiš-Gemer Ore Mountains (Slovakia) and further south in the territory of Hungary. Meliata Unit is formed by two structural-tectonic units that contrast in deformation and metamorphism degree. The first, HP/LT metamorphosed rocks of Bôrka Nappe (Mello et al. 1998) include Permian continental clastics with acidic metavolcanics, Triassic metacarbonates interlayered with basic volcanics and volcanoclastics, followed by thick complex of Jurassic dark phyllites with metasandstones. The second part, Meliata Unit s.s., represents typical ophiolite-bearing mélange including low-grade metamorphosed Jurassic flysch with huge Triassic olistostromes (e.g., Plašienka et al. 2019). The metamorphosed fragments of Middle (Ladinian) to Upper (Carnian) Triassic oceanic cherty shales and radiolarites with N-MORB and OIB in flysch were biostratigraphically and geochronologically defined as the Jaklovce (pre-flysch) paleotectonic unit (Putiš et al. 2019). The lower part of the Bôrka Nappe is lithologically connected with the underlying Gemer Unit Paleozoic basement as a source of siliciclastic sediments. The higher part of inferred Lower to Middle Triassic siliciclastic and carbonatic sediments, with calc-alkaline basic volcanics interlayers (Faryad et al. 2005; Putiš et al. 2019), moreover contains newly discovered rhyolitic metavolcanics at the Hačava village. Magmatic crystallization age of the metarhyolites protolith, dated at 248.5 ± 1.3 Ma on zircon by the LA-ICP-MS (Fig. 1), thus constrains the age of host sediments to Lower (to lower Middle) Triassic. Detrital zircon grains from the Ladinian cherty shales at Jaklovce yielded similar U-Pb SIMS concordia ages of 247 ± 4 Ma, 245.5 ± 3.3 Ma and 243 ± 4 Ma (Putiš et al. 2011, 2019). All these dates within the error fall into the interval of advanced continental rifting stage of Meliaticum (Bôrka paleotectonic unit), predating the formation of the Neotethys oceanic rift determined from the Jaklovce paleotectonic unit in the Ladinian and Carnian.

Acknowledgement: The authors appreciate financial support from the Slovak Research and Development Agency (projects APVV-17-170; APVV-19-0065) and from the Grant Agency for Science, Slovakia (project VEGA 1/0435/21).

References:

Faryad S.W., Spišiak J., Horváth P., Hovorka D., Dianiška I. & Jósza S. 2005. Petrological and geochemical features of the Meliata mafic rocks from the sutured Triassic oceanic basin, Western Carpathians. *Ofioliti*, 30, 27–35.

Mello J., Reichwalder P. & Vozárová A. 1998. Bôrka Nappe: high-pressure relic from the subduction-accretion prism of the Meliata ocean (Inner Western Carpathians, Slovakia). *Slovak Geological Magazine*, 4, 4, 261–273.

Mock R., Sýkora M., Aubrecht R., Ožvoldová L., Kronome B., Reichwalder P. & Jablonský J. 1998. Petrology and petrography of the Meliaticum near the Meliata and Jaklovce villages, Slovakia. *Slovak Geological Magazine*, 4, 223–260.

Plašienka D., Méres Š., Ivan P., Sýkora M., Soták J., Lačný A., Aubrecht R., Bellová S. & Potočný T. 2019. Meliatic blueschists and their detritus in Cretaceous sediments: new data constraining tectonic evolution of the West Carpathians. *Swiss Journal of Geosciences*, 112, 1, 55–81.

Putiš M., Radvanec M., Sergeev S., Koller F., Michálek M., Snárska B., Koppa M., Šarinová K. & Németh Z. 2011. Metamorphosed succession of cherty shales with basalt and diastrophic breccia in olistolith of the Meliatic Jurassic accretion wedge near Jaklovce (Slovakia), dated on zircon (U-Pb SIMS SHRIMP). *Mineralia Slovaca*, 43, 1, 1–18 (in Slovak with English summary).

Putiš M., Soták J., Li Q.-L., Ondrejka M., Li X.-H., Hu Z., Ling X., Nemec O., Németh Z. & Ružička P. 2019. Origin and age determination of the Neotethys Meliata Basin ophiolite fragments in the Late Jurassic–Early Cretaceous accretionary wedge mélange (Inner Western Carpathians, Slovakia). *Minerals*, 9, 652, 1–38.

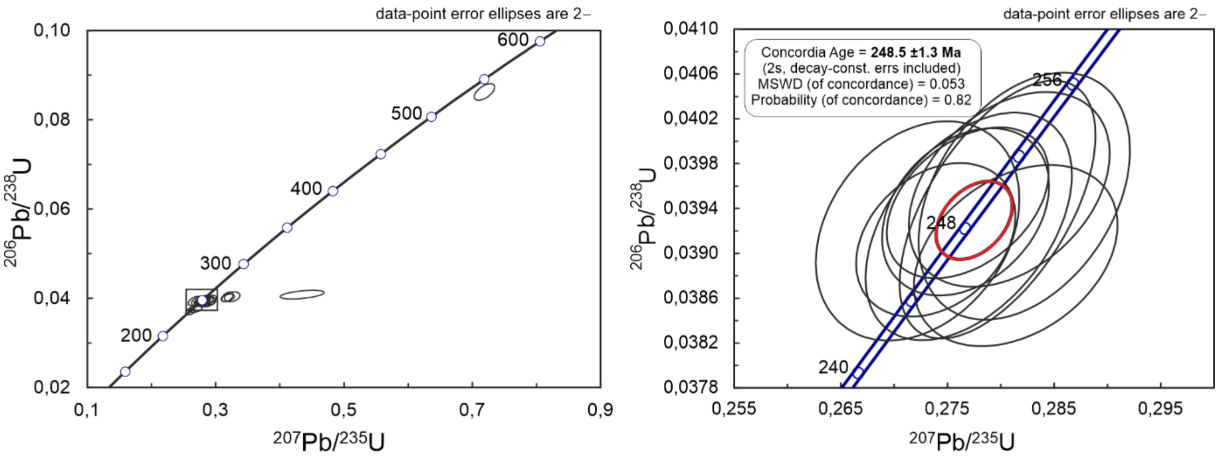


Figure 1: U/Pb concordia diagrams with concordia age of Early (to early Middle) Triassic metarhyolites of the Bôrka paleotectonic unit.

Petrological composition of organic matter in the Oligocene Dynów Marl Member (Menilite Formation, Skole Unit, Polish Outer Carpathians) in Tarnawka and its implication in basin salinity interpretations

WERONIKA PRATKOWIECKA, PATRYCJA WÓJCIK-TABOL,
ALFRED UCHMAN and MARTA OSZCZYPKO-CLOWES

*Institute of Geological Sciences, Jagiellonian University, Gronostajowa 3a,
30-387 Kraków, Poland; e-mail: weronika.pratkowiecka@gmail.com*

Oligocene–Early Miocene Menilite Formation was accumulated in the Paratethys and is regarded a good example of anoxic sediments (e.g., Vető 1987; Köster et al. 1989). It is dominated by deep-water organic-rich black or brown shale facies with a high hydrocarbon generating potential.

The Dynów Marl Member (Lower Oligocene, NP23 Zone) is characterised by the presence of abundant *Reticulofenestra ornata*, endemic species, limited not only in time (NP 23) but also in space (to the Paratethys region). According to Nagymarosy and Voronina (1992) this species is characteristic for the brackish-water environment. The blooms of low-diverse but extremely abundant phytoplankton, e.g., *Reticulofenestra ornata* (Sachsenhofer et al. 2017), resulted in the deposition of calcareous nannoplankton marls forming a widespread horizon in the Paratethys (Sachsenhofer et al. 2018). This event is associated with the complete isolation of the Paratethys and can be traced in both in the Central (Chert Mb. and Dynów Marl of Menilite Fm. in Ždánice-Pouzdřany unit, see Krhovský et al. 1992) and East Paratethys (Polbinian horizon, see Nagymarosy and Voronina 1992).

The petrology of organic matter in the Dynów Marl Member of the Skole Unit has so far been poorly documented. In this study, the maceral composition of organic matter and the mineral composition of lithofacies have been analyzed in the quarry in Tarnawka, S of Łańcut, where dark brown and brown mudstones, sandstones (Borysław Sandstone Member), cherts, and marls (Dynów Marl Member) are exposed. The rocks were analyzed by means of XRD, transmitted, reflected, and blue light microscopic observations.

Microscopic analyses proved that the maceral composition of organic matter depends on lithofacies. The largest share of organic matter occurs in dark brown and brown mudstones, and it is distinctly lower in marls, cherts, and sandstones. The dominant type of organic matter in all lithofacies is marine in origin. This is expressed by the dominance of the liptinite group macerals. A typical maceral association in the Dynów Marl Member is composed of liptodetrinite + lamalginite + vitrodetrinite + inertodetrinite.

Statistical analysis of the amount and size of the alginite macerals (telalginite and lamalginite) may be a useful tool for recognition of salinity during the production and deposition of organic matter. The telalginite/lamalginite ratio (T/L) may indicate changes in algal–microbial communities and/or changes in the degree of preservation of solitary algae (Bechtel et al. 2012). The Dynów Marl Member reveals the shortage of telalginite (T/L = 0.0004) and the presence of the short, narrow, and mostly dispersed straight lamalginite in the background, while organic matter-rich brown mudstones contain more larger and well preserved telalginite (T/L = 0.0242).

The increased size of telalginite macerals may indicate fresh or brackish waters conditions. Furthermore, larger telalginite is considered to be more resistant to degradation than lamalginite due to the higher sinking rate (shorter exposure to oxidative degradation) (Jia et al. 2013). Moreover, salinity is considered as a factor in promoting the activity of carbon-degrading enzymes and intensifying the microbial decomposition. Consequently, OM accumulation decreases concomitantly with salinity increase (Morrissey et al. 2014).

Dark mudstones represent turbiditic deposits enriched in algal and bacterial organic matter produced and preserved in an environment of relatively low salinity. The Dynów Marls Member might record deposition throughout the density stratified water column (brackish photic zone and deeper saline water).

Acknowledgement: The research has been supported by a grant from the Faculty (Geography and Geology) under the Strategic Program Excellence Initiative at Jagiellonian University.

References:

Bechtel, A., Jia, J.L., Strobl, S.A.I., Sachsenhofer, R.F., Liu, Z.J., Gratzer, R. & Püttmann, W. 2012. Paleoenvironmental conditions during deposition of the Upper Cretaceous oil shale sequences in the Songliao Basin (NE China) implications from geochemical analyses. *Organic Geochemistry*, 46, 76–95.

Jia, J., Bechtel, A., Liu, Z., Strobl, S., Sun, P. & Sachsenhofer, R.F., 2013. Oil shale formation in the Upper Cretaceous Nenjiang Formation of the Songliao Basin (NE China): Implications from organic and inorganic geochemical analyses. *International Journal of Coal Geology*, 113, 11–26.

Köster, J., Rospondek, M., Schouten, S., Kotarba, M., Zubrzycki, A. & Sinninghe Damste, J.S. 1989. Biomarker geochemistry of a foreland basin: the Oligocene Menilite Formation in the Flysch Carpathians of Southeast Poland. *Organic Geochemistry*, 29, 649–669.

Krhovský, J., Adamová, J., Hladiková, J. & Maslowská, H. 1992. Paleoenvironmental changes across the Eocene/Oligocene boundary in the Ždánice and Pouzdrany units (western Carpathians, Czechoslovakia): the long-term trend and orbitality forced changes in nannofossils assemblages. *Knihovnicka Zemní plyn a Nafta*, 14b, 2, 105–187.

Morrissey, E.M., Gillespie, J.L., Morina, J.C. & Franklin, R.B. 2014. Salinity affects microbial activity and soil organic matter content in tidal wetlands. *Global Change Biology*, 20, 1351–1362.

Nagymarosy, A. & Voronina, A.A. 1992. Calcareous nannoplankton from the lower Maykopian Beds (Early Oligocene, Union of Independent States). *Knihovnicka ZPN (Zemni Plyna Nafta*), 14b, 2, 189–223.

Sachsenhofer, R.F., Popov, S.V. Coric, S., Mayer, J., Misch, D., Morton, M.T., Pupp, M., Rauball, J. & Tari, G. 2018. Paratethyan petroleum source rocks: an overview. *Journal of Petroleum Geology*, 41, 219–246.

Sachsenhofer, R.F., Popov, S.V., Bechtel, A., Coric, S., Francu, J., Gratzer, R., Grunert, P., Kotarba, M., Mayer, J., Pupp, M., Rupprecht, B.J. & Vincent, S.J. 2017. Oligocene and Lower Miocene source rocks in the Paratethys: Palaeogeographic and stratigraphic controls. *In:* Simmons, M.D., Tari, G.C. and Okay, A. (Eds): *Petroleum Geology of the Black Sea. Geological Society Special Publication, London*, pp. 267–302.

Vető, I. 1987. An Oligocene sink for organic carbon: upwelling in the Paratethys? *Palaeogeography, Palaeoclimatology, Palaeoecology*, 60, 143–153.

Protolith identification of skarnoid xenoliths from Southern Slovakia: New insights from geochemical and isotopic data

LUCA REATO[1], MONIKA HURAIOVÁ[1],
PATRIK KONEČNÝ[2] and VRATISLAV HURAI[3]

1 – Comenius University, Faculty of Natural Sciences, Department of Mineralogy, Petrology and Economic Geology, Ilkovičova 6, 84215 Bratislava, Slovak Republic; e-mail: reato1@uniba.sk

2 – State Geological Institute of Dionýz Štúr, Department of Special Laboratories, State Geological Institute of Dionýz Štúr, Mlynská Dolina 1,81704 Bratislava, Slovak Republic

3 – Institute of Earth Sciences, Slovak Academy of Sciences, Dúbravská Cesta 9, 84005 Bratislava, Slovak Republic

Skarnoid calc-silicate xenoliths composed of anorthite, clinopyroxene and Mg-Al spinel were discovered in the alkali basalts quarry located in the Belinsky vrch lava flow (Southern Slovakia). Randomly oriented tschermakite pseudomorphs are replaced by olivine, spinel, and plagioclase. The relict amphibole within the pseudomorphs is characterized by high ^{VI}Al (1.95–2.1 apfu), and very low occupancy of the A-site (<0.1 apfu), which are a diagnostic feature of high-pressure metamorphic rocks. Pyroxene compositions plot along continuous mixing line extending from nearly pure diopside-augite towards a $Ca(Fe^{3+}Al)AlSiO_6$ endmember with an equal proportion of $^{VI}Al^{3+}$ and Fe3+, towards the kushiroite and esseneite endmembers. Melilite inclusions in these high Al, Fe pyroxenes are suggesting high CO_2 partial pressure, low SiO_2 activity and strongly oxidizing conditions, in which the production of garnet is suppressed, even at high pressures (Ohashi and Hariya 1975). Forsterite ($Fo_{72–83}$) and Fe^{3+}-rich ilmenite crystallized from the melt, leaving behind residual calcic carbonate. Euhedral aragonite and apatite embedded in the fine-grained calcite or aragonite groundmass indicate slow crystallization of residual carbonatite around the calcite-aragonite stability boundary. The application of olivine-ilmenite thermometer (Andersen and Lindsey 1981), the calculation through Perple_X (Connolly 1990), of the calcite-aragonite transition for a CO_2 saturated environment, and the application of the amphibole-plagioclase thermobarometer (Molina et al. 2021) yielded estimates of T = 770 – 860 °C and P = 1.8 – 2.1 GPa. Isotopic analysis conducted on calcite and aragonite display a slightly depleted mantle signature, with $^{87}Sr/^{86}Sr = 0.704$ and $^{143}Nd/^{144}Nd = 0.513$. The clinopyroxenes geochemistry provides important information on the origin and the geological context in which the protolith was formed. The Ca vs. Ti + Cr, and the Ti vs. Al discrimination diagrams of Leterrier et al. (1982) are showing that non-alkalic clinopyroxenes in calc-silicate xenoliths fall within the field of late syn-orogenic tholeiites (Fig. 1). This may represent the pristine composition of the magmatic protolith, unaffected by the metasomatism associated with the carbonatite and the alkali basalt melts. These data, combined with the observation of high Cr contents in spinel and pyroxene, abundant Cu-sulfides and up to 1.0 wt % CaO contents in olivine, suggest a magmatic nature of the protolith, much likely a layered gabbro-anorthosite contaminated by calcic carbonatite melt.

References:

Andersen, D. & Lindsley, D. 1981. A valid Margules formulation for an asymmetric ternary solution: revision of the olivine-ilmenite thermometer, with applications. *Geochimica et Cosmochimica Acta*, 45, 6, 847–853.

Connolly, J. 1990. Multivariable phase diagrams; an algorithm based on generalized thermodynamics. *American Journal of Science*, 290, 6, 666–718.

Leterrier, J., Maury, R. C., Thonon, P., Girard, D. & Marchal, M. 1982. Clinopyroxene composition as a method of identification of the magmatic affinities of paleo-volcanic series. *Earth and Planetary Science Letters*, 59, 1, 139-154.

Molina, J., Cambeses, A., Moreno, J., Morales, I., Montero, P. & Bea, F. 2021. A reassessment of the amphibole-plagioclase NaSi-CaAl exchange thermometer with applications to igneous and high-grade metamorphic rocks. *American Mineralogist*, 106, 5, 782–800.

Ohashi, H. & Hariya, Y. 1975. Phase relation of CaFeAlSiO6 pyroxene at high pressures and temperatures. The Journal of the Japanese Association of Mineralogists, *Petrologists and Economic Geologists*, 70, 3, 93–95.

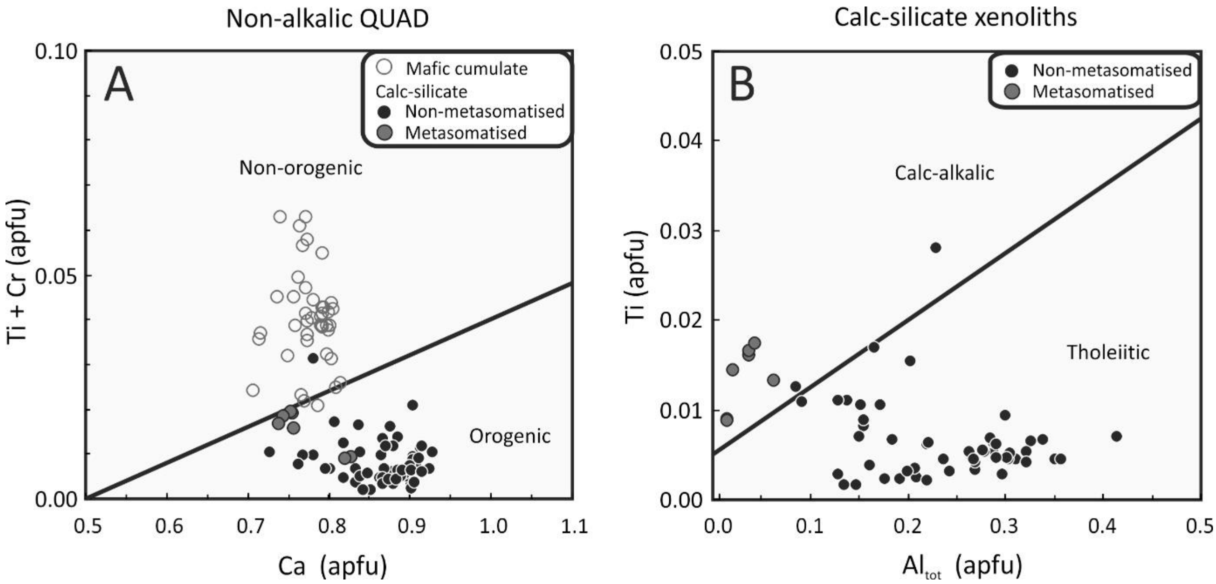


Figure 1: Genetic discrimination diagrams (Leterrier et al. 1982) for non-alkalic clinopyroxenes with data points from mafic cumulates and calc-silicate xenoliths from the Southern Slovakia Volcanic Field.

Possible fossil medusae in the Eocene flysch from the Slovenian coast

BOŠTJAN ROŽIČ[1], ALFRED UCHMAN[2], LUKA GALE[1,3] and TIMOTEJ VERBOVŠEK[1]

1 – University of Ljubljana, Faculty of Natural Sciences and Engineering, Department of Geology, Aškerčeva 12, SI-1000 Ljubljana, Slovenia; e-mail: bostjan.rozic@ntf.uni-lj.si

2 – Institute of Geological Sciences Jagiellonian University, Oleandry 2a, PL-30-063 Krakow, Poland

3 – Geological Survey of Slovenia, Dimičeva 14, SI-1000 Ljubljana, Slovenia

The study area is located in the Slovenian coastal area, which structurally belongs to an Adria Foreland, near the Dinaric Thrust Front. Eocene flysch deposits characterize the entire area, with the basement of Eocene limestone outcropping only in the core of the Izola anticline. The flysch generally has a very distal character and consists of alternating marls and thin-bedded, fine-grained siliciclastic turbidites. Prominent layers are up to 9 meters thick calciturbidites. Exceptionally, near the town of Škofije, an interval of thick-bedded, medium-grained sandstone is quarried. During the sedimentological study of these beds it became evident that they are rich in various ichnofossil and sedimentary structures. In addition to known ichnofossils, unusual circular shapes were discovered on the lower bedding plane of a particular thicker sandstone bed and examined in more detail. Several boulders from this bed were found in the quarry, and all specimens were measured on site. The boulder with the best specimens was cut into a 10 cm thick slab and taken to the laboratory for further examination. All specimens were described in detail, thin sections were made through the selected specimen, and the surface of the bedding plane was scanned with a laser scanner for further digital morphometric analysis. These fossils exhibit positive relief, are circular to ellipsoidal, and vary in diameter from 6.5 to 24.5 cm. They are generally isolated, but some overlap each other. The best preserved specimens have two rings and radially disturbed thin "rays" between them. Additional small transverse rods can be observed in the central part, although poorly expressed. We assume that these fossils are remains of medusae. They lay on the marly seafloor after the great medusae bloom, probably dead. Soon they were covered by a layer of sand that pushed them into the marl, and after the soft tissue decayed, the sand entered the space formed by the medusae. Thin sections show that only the lowermost laminae were deformed by the filling, while already in the thin sections some continuous laminae can be seen. This suggests that this bed was probably not turbiditic, but was formed by a different sedimentation process, probably by a hyperpycnal flow that gradually accumulated the sand above the seafloor. This interpretation is also supported by the absence of erosional textures on the bedding plane. In the laboratory, we also conducted an experiment with recent medusae from the Gulf of Trst/Trieste. They were placed on the mud from the quarry ponds and covered with several centimeters of quartz sand of the grain size determined from the thin sections.

Acknowledgement: The research was financially supported by the Slovenian Research Agency (research core funding No. P1-0195, research projects No. J1-2477 and No. J1-1712).

Pleistocene aeolian erosion and wind system in Slovakia

KRISZTINA SEBE[1] and MICHAL ŠUJAN[2]

1 – Department of Geology and Meteorology, University of Pécs, Ifjúság ú. 6, Pécs, Hungary; e-mail: sebe@gamma.ttk.pte.hu

2 – Department of Geology and Paleontology, Faculty of Natural Sciences, Comenius University in Bratislava, Ilkovičova 6, Bratislava, Slovak Republic

Wind erosion features like wind-polished pebbles and rock surfaces or wind-carved landforms carry important information on past air flow systems. Because of the dominantly mountainous topography, Slovakia does not abound in such features. Still, they are present, especially in the southern, lower-lying parts of the country. In 2014 and 2015, investigations were carried out to identify past wind directions from erosional features, compare the data with those from neighbouring countries and interpret them in a regional palaeoclimatic framework.

Data on the existence of pebble and bedrock ventifacts were gathered from the literature, and promising sites were investigated in the field. Mesoforms of wind-eroded surfaces were documented and measured. For large landforms, topographic maps and digital elevation models were considered. Observations showed that there are much fewer occurrences of wind erosion features than in Austria or Hungary. The best-preserved wind-sculpted surfaces are preserved on quartzites (Fig. 1), similarly to other areas. Polish and wind-eroded keels are often well-developed, while precise wind direction indicators like flutes and grooves are weakly developed and only occur at a few places. On steep rocks standing out from their surroundings, wind polish is visible up to great (8 – 10 m) heights at some places, pointing either to strong upslope air currents or to fast denudation and weathering out of resistant rocks. Based on luminescent age determinations of blown sand movement as indirect data, wind erosion was possible at least during the Würmian and even during the Holocene.

Flutes and grooves on bedrock ventifacts point to W to WNW winds in W Slovakia, around the Devín Gate, and to N winds in the east. These data are coherent with the orientation of wind corridors (straight wind-carved valleys) and wind directions reconstructed from sand dunes as well as with data measured in Austria and Hungary. They indicate that topography exerted strong control on near-surface air flow, funneling winds in the low-lying portions of the mountain ranges surrounding the Pannonian Basin. Westerly winds indicate that the Fenno-scandian ice sheet had no significant impact on the local air circulation.

Apart from the erosional features observed on morphostructures formed by pre-Cenozoic rocks, selective deflation is considered as a formative process of the Late Pleistocene to Holocene depression of Lake Šúr (NE of Bratislava). The depression formerly assumed to be of tectonic origin is situated above Miocene sands and muds of low resistance to eolian erosion and is surrounded by much more resistant Quaternary fluvial gravels. This setting is comparable to those observed around Lake Neusiedlersee. The depression is in ideal position for overdeepening by wind in the lee of a topographic obstacle, the Malé Karpaty Mts., similarly to Lake Balaton and Lake Velence in Hungary and to Lake Neusiedlersee. The thickness of the lacustrine and paludal deposits of all mentioned lakes is very low, reaching only a few meters, and lack evidence of deformation by faults. Hence, the formation of the Lake Šúr morphological depression is another expression of periglacial wind activity in the region.

Acknowledgement: Research was supported by the CEEPUS Mobility Grant 1415-83744. We are grateful to Miloš Stankoviansky for his help with the literature, field work and consultations.

Figure 1: Wind-polished flutes on 'Dog's Rock' on Devínska Kobyla.

Miocene andesite volcanism in the Mecsek Mts, SW Hungary

KRISZTINA SEBE[1], LEVENTE LAISZ[1] and SZABOLCS HARANGI [2, 3]

1 – Department of Geology and Meteorology, University of Pécs, Ifjúság ú. 6., Pécs, Hungary; e-mail: sebe@gamma.ttk.pte.hu

2 – Eötvös Loránd University, Institute of Geography and Earth Sciences, Department of Petrology and Geochemistry, Budapest, Hungary

3 – MTA-ELTE Volcanology Research Group, Budapest, Hungary

The Neogene succession of the Mecsek Mts. in SW Hungary includes significant andesite bodies, classified into the Komló (formerly Mecsek) Andesite Fm. and traditionally considered to be of Ottnangian age. Despite their relatively large volume, there are still many open questions, such as ones regarding their genesis (effusive or subvolcanic) and their stratigraphic position. Recently, new investigations were carried out in order to improve our understanding. More than 200 borehole successions were reviewed using a uniform stratigraphic scheme and entered into a geographic information system (GIS). Geological cross-sections and 3D model surfaces were constructed using ArcGIS and RockWorks. Petrographic and geochemical examinations were also performed.

The main andesite body in the central Mecsek Mts., in the town of Komló, has an extent of ~2.8×2.8 km (4.05 km^2) and a maximum drilled thickness of 310 m. Its volume is 0.45 km^3. Stratigraphically it lies at unit boundaries, not intruded into given units. It is underlain by the Mesozoic basement, the Lower Miocene fluvial Szászvár Fm. or by the Lower Miocene Tihamér (previously Gyulakeszi or 'lower') Rhyolite tuff. It is covered by the Komló Clay marl Mb. of the Lower to Middle Miocene lacustrine Kiskunhalas Fm. The andesite was displaced by a major post-formational fault. Sporadic occurrences of sills and dykes are known from some boreholes. The andesite is sparsely porphyritic and contains orthopyroxene and amphibole in addition to the dominant plagioclase phenocrysts embedding in a glassy to microcrystalline groundmass. The bulk rock composition differs from the typical calc-alkaline andesites and shows relatively high Na_2O. Contrary to the previously published K/Ar age of ~20 Ma, the stratigraphic position of the andesite just below the Karpatian-Badenian lacustrine succession points rather to a Karpatian age. On the other hand, the andesite shows many similarities with the 18.5 Ma old andesitic to dacitic succession found in borehole sections near Paks.

In the northern Mecsek Mts. the buried andesite body was exposed by five boreholes. Its dimensions are similar – at the same order of magnitude – as those of the Komló volcano: 1.6×2.5 km in the horizontal plane and a maximum exposed thickness of 192 m. Based on core documentations, this andesitic body seems to lie in a different stratigraphic position. It overlies either the Mesozoic basement, or the basement plus some rhyolite tuff; the fluvial Szászvár Fm. does not occur below it. The andesite is covered everywhere by rhyolite tuff (Tihamér/Gyulakeszi Fm.?), then by thick fluvial sandstones and conglomerates of the Szászvár Fm.

Besides their stratigraphic position, eroded and reworked andesite pebbles in the overlying sediments described in core documentations also indicate that the andesites both at Komló and in the northern Mecsek Mts. were formed by effusive processes. Based on the agglomerates at the bottom and top of the andesite bodies and the lack of pyroclastics, they can be interpreted as lava domes. Lava viscosity was relatively low, resulting in a moderate height and extended lateral spread compared to andesite lava domes in general. The stratigraphy and the presumed age of the Mecsek andesite volcanism imply a connection to the initial rifting stage of the Pannonian basin similarly to some volcanoes reported from Croatia and this is consistent with its geochemistry. This volcanism along with those revealed around Paks could have played a significant role in the initiation of rifting by pre-heating and thus weakening the crust.

Acknowledgement: Research was supported by the National Research, Development and Innovation Office project 138638.

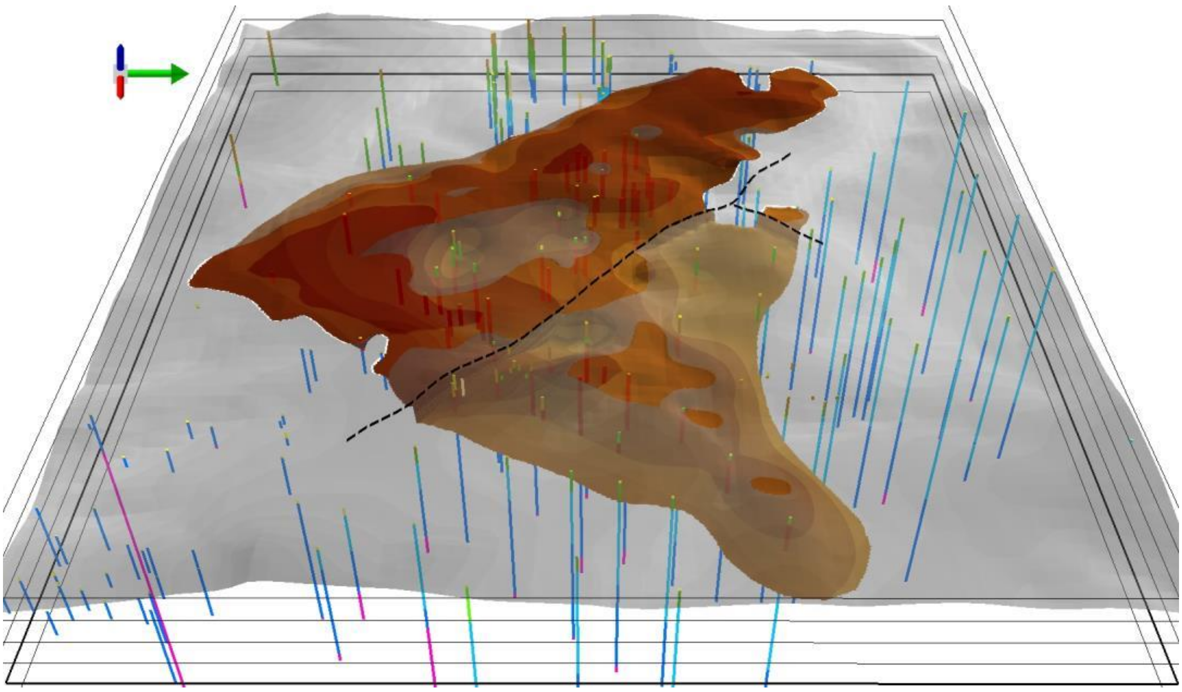


Figure 1: 3D model of the top surface of the Komló volcano and the boreholes used for construction. Arrow points to north.

Multiproxy reconstruction of a gradual prodeltaic evolution during the Miocene Climate Optimum

FILIP SCHEINER[1,2], MARTINA HAVELCOVÁ[3], KATARÍNA HOLCOVÁ[1], NELA DOLÁKOVÁ[4], SLAVOMÍR NEHYBA[4], LUKÁŠ ACKERMAN[2], JAKUB TRUBAČ[5], TORSTEN UTESCHER[6,7], ŠÁRKA HLADILOVÁ[4] and JAN REJŠEK[2]

1 – Institute of Geology and Palaeontology, Charles University, Albertov 6, 128 43 Praha 2, Czech Republic; e-mail: filip.scheiner@natur.cuni.cz

2 – Institute of Geology of the Czech Academy of Sciences, Rozvojová 269, 165 00 Praha 6 Lysolaje, Czech Republic

3 – Institute of Rock Structure and Mechanics AS CR, V Holešovičkách 41, 182 09 Praha 8, Czech Republic

4 – Institute of Geological Sciences, Faculty of Science, Masaryk University, Kotlářská 2, 611 37, Brno, Czech Republic; nela@sci.muni.cz

5 – Institute of Geochemistry, Mineralogy and Mineral Resources, Faculty of Science, Charles University, Albertov 6, 128 00 Prague 2, Czech Republic

6 – Senckenberg Research Institute and Natural History Museum / Biodiversity and Climate Research Centre, Senckenberganlage 25, Frankfurt am Main, Germany

7 – Steinmann Institute, Bonn University, Nussallee 8, Bonn, Germany

Biomarker studies, including n-alkane analysis, coupled with traditional palaeobiological approaches are promising tools for identification of continent-sea interactions even in the case of heterogeneous sedimentary record that is common e.g., in epicontinental marine environments. This study provides a detailed reconstruction of gradual developmental stages of a prodeltaic system that was formed during the Miocene Climate Optimum in an epicontinental sea – the Paratethys. The studied locality - Hevlín quarry is an active mine with heterochronous sediments, representing probably different biotopes, that were deposited during the Miocene Climate Optimum (MCO) in the Carpathian Foredeep, which was a part of the Central Paratethys marine realm. The Hevlín deposits were firstly described in the 1960's and designed as the parastratotype of the regional Central Paratethys stage Karpatian (Cicha et al. 1967; Brzobohatý et al. 2003). This regional stage represents the upper Burdigalian time interval (16 – 17.2 Ma).

To reconstruct continent-sea interactions at this locality our study applied an interdisciplinary multiproxy approach including n-alkane analysis, $\delta^{13}C_{organics}$, biomarker studies, Strontium Isotope Stratigraphy (SIS), $\delta^{18}O$ and $\delta^{13}C$ stable isotopes on foraminifera, sedimentology, paleobiology and palynological analysis along with the Coexistence Approach and Plant Functional Type approach.

The studied sedimentary succession represents a complex of prodeltaic related deposits in several developmental stages. There are several different horizons with variable fossil fauna, which reflect paleoenvironmental settings linked with a variable freshwater influence during the prodelta evolution.

The faunal analysis and stable isotopes of carbon and oxygen on foraminifera revealed heterogeneous assemblages, which often indicate a presence of stress factors in the environment. There are common horizons with intensive reworking of microfossils that further complicate the use of biostratigraphy in this area. The joint use of calcareous nannoplankton and foraminiferal biostratigraphical markers together with $^{87}Sr/^{86}Sr$ stratigraphy enabled to correlate the section with the broader Burdigalian/Langhian boundary interval (Miocene Climatic Optimum).

The palynological analysis points to a flat landscape relief around the sedimentation area with warm temperate to subtropical climate. The mean annual temperature range estimate is 17 – 19.5 °C. Both profiles show a relatively high climatic seasonality with only two intervals of more oceanic type of climate. A persistence of forest cover with stabile peatland environments and lower share of herbs and shrubs in the neighbouring continental realm were indicated.

Organic geochemistry including n-alkane indices and a biomarker study enabled to identify particular developmental stages of the prodeltaic environment based on the provenance of organic matter. The specific suite of biomarkers indicated stages with a predominant marine productivity, alternating with stages where organic matter of terrestrial origin is clearly dominant by increased effect of the parent deltaic system. The biomarker study is in a close agreement with the analyzed palynospectra.

References:

Brzobohatý, R., Cicha, I., Kováč, M. & Rögl, F. (Eds.) 2003. *The Karpatian a Lower Miocene Stage of the Central Paratethys.* Masaryk University Brno, 360 pp.

Cicha, I., Seneš, J. & Tejkal, J. (Eds.) 1967. *Chronostratigraphie und Neostratotypen, Miozän der Zentralen Paratethys. M3 Karpatien*. VSAV Bratislava, 312 pp.

Rare Middle Triassic coleoids from the Western Carpathians

JÁN SCHLÖGL[1], MARTIN KOŠŤÁK[2], DIRK FUCHS[3], MILAN HAVRILA[4],
TEA KOLAR-JURKOVŠEK[5], ATTLIA VÖRÖS[6] and JURAJ ŠURKA[7]

1 – Department of Geology and Palaeontology, Faculty of Natural Sciences, Comenius University in Bratislava, Slovak Republic; e-mail: janci.schlogl@gmail.com

2 – Institute of Geology and Palaeontology, Faculty of Science, Charles University, Prague, Czech Republic

3 – SNSB-Bayerische Staatssammlung für Paläontologie und Geologie, Munich, Germany

4 – Slovenská geologická spoločnosť, Bratislava, Slovak Republic

5 – Geological Survey of Slovenia, Ljubljana, Slovenia

6 – Hungarian Natural History Museum, Budapest, Hungary

7 – Earth Science Institute, Slovak Academy of Sciences, Banská Bystrica, Slovak Republic

The two stratigraphically well labeled (by ammonites and conodonts) coleoid remains have been recorded in the Triassic dark-grey organodetritic limestones (Ráztoky Limestone) of Western Carpathians (Hronic Nappe). The facies originated betwen carbonate ramp and basinal development. It yields diversificated cephalopod fauna including nautiloids (2 taxa), ammonoids (7 taxa) and indetermined aulacoceratids. Two unusual coleoid specimens are putatively referred to genus *Mojsisovicsteuthis* (incomplete, 40 mm long, laterally compressed phragmocone with typical oval cross-section and slightly undulate suture lines) and possibly, a new taxon slightly resembling *Breviconoteuthis* (Phragmoteuthida; complete - 64mm long, cyrtoconic, dorso-ventrally compressed phragmoconus). Based on index ammonites and conodonts, both records are of the uppermost Trinodosus through the lowermost Reitzi Zones (Anisian – Lower Illyrian).

Peculiar microstructure of the outer shell wall in the Lower Miocene *Aturia* from the Central Paratethys (Vienna Basin, Western Carpathians, Slovakia)

JÁN SCHLÖGL [1], ADAM TOMAŠOVÝCH [2], NATÁLIA HUDÁČKOVÁ [1] and STANISLAVA MILOVSKÁ [3]

1 – Department of Geology and Paleontology, Faculty of Natural Sciences, Comenius University in Bratislava, Slovak Republic; e-mail: janci.schlogl@gmail.com

2 – Earth Science Institute, Slovak Academy of Sciences, Bratislava, Slovak Republic

3 – Earth Science Institute, Slovak Academy of Sciences, Banská Bystrica, Slovak Republic

The outer shell wall in both the extant *Nautilus* and the extinct ammonoids invariably consists of four layers. They include (1) outermost organic periostracum (produced inside the periostracal groove on the outer mantle edge), (2) outer prismatic-sphaerulitic (in *Nautilus*) or prismatic layer (in ammonoids), (3) nacreous layer (outer prismatic and nacreous layers are produced by a mantle zone immediately posterior to the mantle edge), and (4) inner prismatic layer (produced by myoadhesive epithelium in the posterior part of the body chamber).

However, shells of *Aturia* preserved in the Miocene diatom-rich clays of the Vienna Basin, deposited in the upper bathyal zone at water depths ~200 – 300 m (based on foraminiferal assemblages), show a unique shell preservation: the outer prismatic layer is either missing or represented by unique, irregular patchy coatings formed by prismatic crystals. This preservation is not generated by postmortem dissolution and alteration. First, the outer surface of the nacreous layer does not show any signs of dissolution and possesses growth lines that are directly encrusted by encrusting polychaete tubes (on the outer surface of body chamber), leaving a clear shallow attachment scar on the surface of the nacreous layer. Second, all species with aragonitic shells preserved in diatom-rich muds and co-occurring with *Aturia* show pristine preservation. Third, the *Aturia* assemblage is characterized by co-occurrence of shells and jaws and is thus autochthonous (Schlögl et al. 2011).

The views of the shell wall in SEM images shows a very thick (175 – 220 μm for 18 – 25 mm in D) nacreous layer underlain by a distinct, relatively thick inner prismatic layer (40 – 70 μm, up to 110 μm on the septum-shell wall intersection). In contrast, there is no continuous outer prismatic layer, especially on the adult whorls. However, the juvenile and the subadult whorls possess very thin, irregular, discontinuous, patchily-distributed aragonitic coatings formed by prismatic crystals, overlying the nacreous layer. In plane views, these coatings have conspicuous meandriform or labyrinthine shapes, locally forming just strings (4 – 8 μm for the above mentionned D, up to 3 – 4 μm on juveniles below 10 mm in D). In cross-sectional views, the prismatic crystals are oriented more or less perpendicularly or slightly oblique relative to the shell surface in centers of coatings, but become more oblique or even parallel with the external surface of the underlying nacreous layer approaching the margins or edges of the coatings. Therefore, this outer prismatic coating represents a conspicuous type of poorly-developed outer prismatic layer (OPL).

The crystal orientation, preservation of the nacreous layer, and epibionts indicate that these peculiar coatings are not generated by postdepositional alteration or dissolution, and the patchiness is the primary feature of the biomineralization process. The nacreous layer was effectively an external shell layer in the adult stage of *Aturia* because the OPL coatings can be observed only on juveniles or subadults up to 20 – 25 mm (exceptionally up to 30 mm). OPL coatings tend to be very thin on the early juveniles (making a very thin almost continuous layer with very irregular surface), whereas they are thicker and more discontinuous in larger specimens at 20 – 25 mm.

A thin gap or discontinuity occurs at the boundary between the nacreous layer and the OPL coatings, in contrast to the boundary between the inner prismatic layer and the nacrous layer without any gap. Owing to this discontinuity, the coatings frequently partly or fully detach from the nacreous layer during the extraction of specimens from marls and remain preserved just on the imprint.

References:

Schlögl, J., Chirat, R., Balter, V. Joachimski, M. Hudáčková, N. & Quillévéré, F. 2011. Aturia from the Miocene Paratethys: An exceptional window on nautilid habitat and lifestyle. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 308, 330–338.

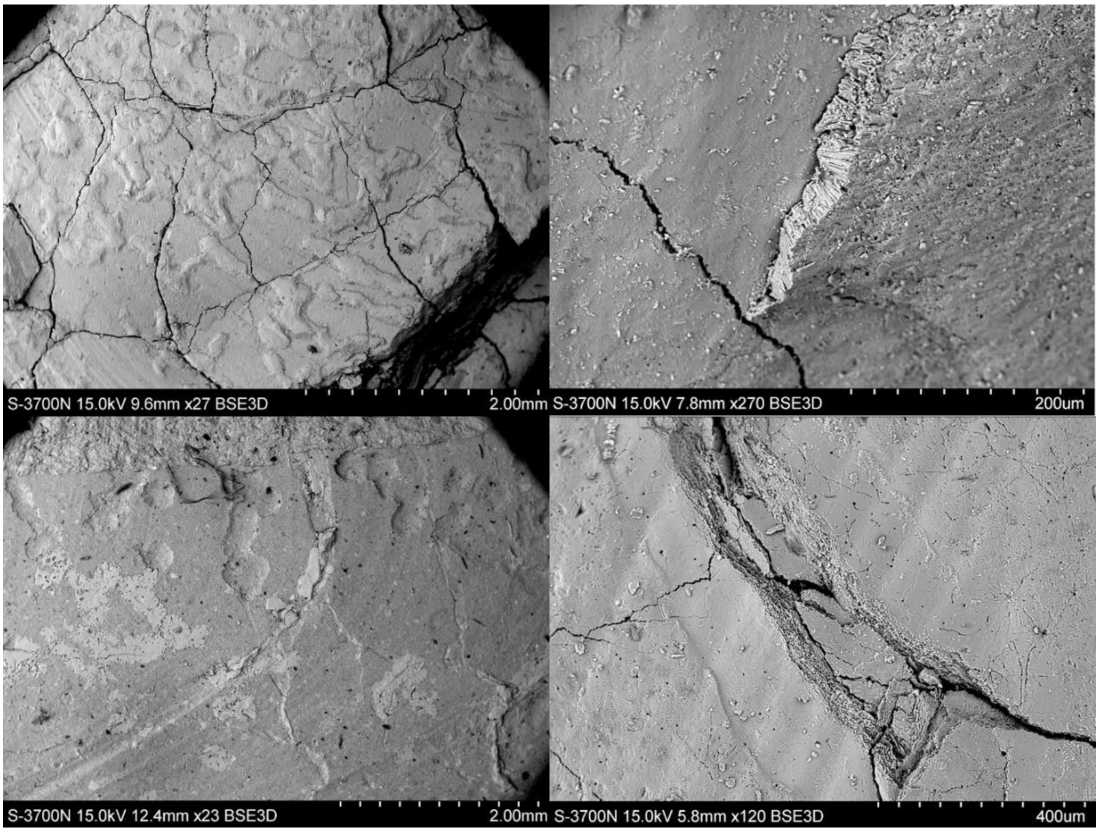


Figure 1: *Aturia* sp., upper Burdigalian, Cerová. A. Discontinuous OPL on the midlle part of flank at approx. 18 mm in D. B. Detail of the microstructure of the wedging out OPL coating. C. Imprint of an aturia fragment with OPL coatings partly detached (white) and partly still attached on the counterpart (pits and furrows). D. Attachment scar of a polychaete tube which clearly shows that the tube was attached directly to the nacreous layer with growth lines. D of the aturia is approx. 22 mm.

Trace fossil association within Sinemurian/early Pliensbachian carbonate sequence of the São Pedro de Moel section (Lusitanian Basin, Portugal) in relation to changes in sedimentary environment

VLADIMÍR ŠIMO[1], ADAM TOMAŠOVÝCH[1],
JÁN SCHLÖGL[2] and DUARTE LUÍS VÍTOR[3]

1 – Geological Division, Earth Science Institute, Slovak Academy of Sciences, Dúbravská cesta 9, 840 05 Bratislava, Slovak Republic; e-mail: vladimir.simo.13@gmail.com

2 – Department of Geology and Paleontology, Faculty of Natural Sciences, Comenius University, Šafárikovo námestie 6, 814 99 Bratislava, Slovak Republic

3 – MARE and Departamento de Ciências da Terra, Universidade de Coimbra, Polo II, Rua Silvio Lima, 3030-790 Coimbra, Portugal

This contribution is focused on analysis of trace fossil assemblages from the upper Sinemurian – lowermost Plliensbachian recorded in the reference section of São Pedro de Moel, western Iberia margin (Portugal).

The sedimentary succession at this section developed from a relatively shallow water, restricted inner-mid ramp environment during the late Sinemurian up to outer ramp environment during the early Pliensbachian (Duarte et al. 2010). The succession is formed by the Água de Madeiros Formation, consisting of two members: the Polvoeira Member with frequent occurrences of black shales and the Praia da Pedra Lisa Member, involving the Oxynotum – lowermost part of the Jamesoni Zone (Duarte et al. 2014). Most of the studied part of the section belongs to the Polvoeira Member. The affiliation in the lowermost part of the section, which may be part of the uppermost part of the Coimbra Formation, is questionable.

The succession at São Pedro de Moel consists of bioclastic marls and carbonates in the basal part (Oxynotum Zone), characterized by high abundance of bivalves, brachiopods, ostracods, ammonites, belemnites, and calcareous nannoplankton (Plancq et al. 2016; Paredes et al. 2013a,b). Abundance of benthic macrofauna markedly decline in the Raricostatum Zone and in the lowermost parts of the Jamesoni Zone (Duarte et al. 2014).

Stratigraphic changes in the composition of trace-fossil assemblages reflect bathymetric and hydrodynamic and water-column stratification changes that occurred during the deposition of the whole succession. The lowermost part of the Água de Madeiros Formation is formed by an alternation of shallow-marine assemblages with *Diplocraterion* with assemblages with abundant traces of *Rhizocorallium* and *Thalassinoides*. Associations of *Thalassinoides* and *Rhizocorallium* traces document deeper conditions and the emergence of *Diplocraterion* (and burrows of pholadomyid bivalves) document shallower conditions. The lower part of the succession (base of the Polvoeira Member, Oxynotum Zone), based on the common occurrence of *Diplocraterion*, can indicates probably at least four transgressive-regressive parasequences. The cyclic alternations of *Diplocraterion* and *Rhizocorallium* and *Thalassinoides* with the gradual disappearance of *Diplocraterion* in the overlying layers reflects a gradual deepening of the marine environment. Gradual deepening associated with increasing frequency of marly laminated intervals is visible in the upper part of the Oxynotum Zone. Disappearance of

Rhizocorallium and the overall decline in diversity and size of trace fossils towards high abundance of tiny *Thalassinoides* and occurrences of layers with monospecific *Planolites*-type bioturbation can be observed in the upper part of the Polvoeira Member (Raricostatum Zone), together with monospecific bivalve pavements (*Meleagrinella*, *Pseudomytiloides*).

The uppermost part of the Polvoeira Member, above the Sinemurian/Pliensbachian boundary, still contains sporadic occurrences of *Planolites,* without any *Thalassinoides* and bivalve pavements The decline in abundance and diversity of trace fossils during the Raricostatum Zone coincides with the maximum deepening (Duarte et al. 2010) and the development of regimes alternating between water column stratification and intense water mixing (Plancq et al. 2016).

However, an increase in diversity and abundance of trace fossils, with *Thalassinoides*, *Planolites*, *Chondrites* and *Phycosiphon*, occurs in the uppermost part of Polvoeira Member, prior to the deposition of the tempestitic Praia da Pedra Lisa Member. A brief sketch of the evolution of the trace fossils indicates that the ethological character of burrowing assemblages changed from shallow-water dwellings (*Diplocraterion*), suspension feeders (*Rhizocorallium*) and open burrow systems (*Thalassinoides*) to deeper-water forms of substrate eaters in the upper part of the described profile (*Planolites* small *Thalassinoides*, *Phycosiphon*).

Acknowledgement: This contribution was supported by grant APVV 17-0555.

References:

Duarte, L.V., Comas-Rengifo, M.J., Silva, R.L., Paredes, R. & Goy, A. 2014. Carbon isotope stratigraphy and ammonite biochronostratigraphy across the Sinemurian–Pliensbachian boundary in the western Iberian margin. *Bulletin of Geosci*ences, 89, 4, 719–736.

Duarte, L.V., Silva, R.L., Oliveira, L.C.V., Comas-Rengifo, M.J. & Silva, F. 2010. Organic-Rich facies in the Sinemurian and Pliensbachian of the Lusitanian Basin, Portugal: Total organic carbon distribution and relation to transgressive-regressive facies cycles. *Geologica Acta*, 8, 3, 325–340.

Paredes, R., Comas-Rengifo, M.J., Duarte, L.V. & Goy, A. 2013a. Braquiópodes do Sinemuriano superior da região de S. Pedro de Moel e de Peniche (Bacia Lusitânica, Portugal). *Comunicaçõe Geológicas*, 100, 29–35.

Paredes R., Comas-Rengifo M.J., Duarte L.V. 2013b. Bivalves from Água de Madeiros Formation (Upper Sinemurian) of the Lusitanian Basin (Portugal). *Comunicações Geológicas*, 100, 21–27.

Plancq, J., Mattioli, E., Pittet, B., Baudin, F., Duarte, L.V, Boussaha, M. & Grossi, V. 2016. A calcareous nannofossil and organic geochemical study of marine palaeoenvironmental changes across the Sinemurian/Pliensbachian (early Jurassic, ~191 Ma) in Portugal. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 449, 1–12.

Red infills of megalodontid bivalves in the Pod peski Valley in Krn mountain range

LUCIJA SLAPNIK[1], BOŠTJAN ROŽIČ[1], LUKA GALE[1,2], PETRA ŽVAB ROŽIČ[1] and ANNA WAŚKOWSKA[3]

1 – University of Ljubljana, Faculty of Natural Sciences and Engineering, Department of Geology, Aškerčeva 12, SI-1000 Ljubljana, Slovenia; e-mail: lucija.slapnik@ntf.uni-lj.si

2 – Geological Survey of Slovenia, Dimičeva 14, SI-1000 Ljubljana, Slovenia

3 – Faculty of Geology, Geophysics and Environmental Protection, AGH University of Science and Technology, Mickiewicza 30, Krakow, 30-059, Poland

We have examined red fillings of the Upper Triassic megalodontid bivalves at a selected location in the Julian Alps (NW Slovenia), in the Pod Peski Valley. Based on optical and cathodoluminescent microscopy and X-ray fluorescence analysis (XRF), we confirmed four generations of shell infillings. First three infillings were attributed to early diagenetic, paleokarstic processes, whereas the origin of the last generation of the sediment infill in megalodontids remained unanswered, and we decided to further examine this area. We described and sampled the rock sequence a few meters below and above the »main« layer with the above-mentioned megalodontids. Already during the previous sampling campaign, we noticed that solution voids appear in the surrounding rocks. These voids are filled with reddish sediment infill, similar to that in the megalodontids. In order to further study neptunian dykes and their impact on fillings in the last generation, we investigated in more detail seven neptunian dykes in the surrounding area. Based on selected samples, we performed a detailed microfacies analysis of sediment sequence and neptunian dykes. The studied section of Dachstein limestone mainly consists of intraclastic peloidal packestone to wackestone with larger bioclasts (megalodontides, gastropods) and solution voids. In a few samples, we observed a presence of *Thaumatoporella*. Stromatolites and emersion breccias with black intraclasts (»black pebbles«) appear in the upper part of the section. These intraclasts also appear in some places in red paleokarst solution voids. In the solution voids, we observed a multi-generational filling with alternation of calcite cement and red sedimentary fillings. The investigated neptunian dykes were generally divided on the basis of dimensions and location of occurrence. Two of them, located directly on the »main« layer with red-filled megalodontids, contain planktonic foraminifera, which indicates the Middle Jurassic or younger age. The next two studied dykes are located just above the »main« layer, one of which contains clasts with calpionellis, characteristic of the Late Jurassic / Early Cretaceous. The last dyke we explored is located a few tens of meters away from the »main« bedding plane and is much larger than all the previous ones. It is a hundreds of meters long, with diverse sedimentary fillings indicating several separate generations of filling. In a few sample from this dyke we identified Early Cretaceous planktonic foraminifera. Based on microscopic analysis, the reddish paleokarst sedimentary fillings in the solution voids were found to be remarkably similar to the sedimentary fillings of the first and second phases in the megalodontid bivalves. The fillings are part of the more complex paleokarst system observed in the Dachstein limestone. More important findings, related to the last generation, were also found in the neptunian dykes, where optical microscopy also showed similarity between the last sediment filling in megalodontids and some neptunian dykes on the »main« bedding plane. Additionally, we discovered a Santonian – Maastrichtian sedimentary filling with globotruncanid foraminifers in the upper part of the succession in one of the solution voids.

Backstop thrusting, inverted duplexes and mélange formations in the Peri-Klippen and Central Carpathian units in northern Slovakia

JÁN SOTÁK[1,2] and MARÍNA MOLČAN MATEJOVÁ[3]

1 – Earth Science Institute, Slovak Academy of Sciences, Ďumbierska 1, 974 11 Banská Bystrica, Slovak Republic; e-mail: sotak@savbb.sk

2 – Faculty of Education, Catholic University in Ružomberok, Hrabovská cesta 1, 03 401 Ružomberok, Slovak Republic

3 – Faculty of Natural Sciences, Comenius University, Ilkovičová 6, 842 15 Bratislava 4, Slovak Republic; e-mail: marina.metejova@uniba.sk

Backthrust stacking of the frontal part of the Central Western Carpathian units has been found in the Malá Fatra Mts and Strážovské vrchy Mts. Such backthrusts, which in some places affected also the Paleogene sediments, were recognized as internal nappe duplexes or south-verging reverse faults of Fatric-Hronic nappes. A new zone of backthusting has been located in northern part of the Veľká Fatra Mts, in several drills throughout the Korbeľka structure. Moreover, these thrust sheets of the Krížna Unit are tectonically superposed on the Paleogene sediments providing a good opportunity to study their stratigraphic and structural discordance. Middle Triassic dolomites of the Choč Nappe are overlapped by the Paleogene sediments, represented by basal carbonate breccias, passing into pelagic sequence of grey marlstones, occasionally with coralgal limestones and nummulitic-rich intervals. Paleogene formations are overthrusted by Lower Cretaceous shales, which markedly differ from underlying marlstones by ductile/brittle deformation, refolding, parallel-bedding shearing, veining, etc. Lower Cretaceous shales are intercalated by volcanic bodies (hyaloclastites, greenish limburgites), which in some drill sections directly overlain the Paleogene marlstones. Tectonic superposition is clearly proved by occurrence of Middle Eocene microfauna in underlying marlstones (e.g., *Hantkenina*, *Acarinina,*) and Lower Aptian microfauna in overlying shales (e.g., *Paraticinella*, *Hedbergella*). Their overturned position is also indicated by inverse zonality of illitization with a higher alteration of the Cretaceous shales (130 – 170°C) and lower alteration of the Paleogene marlstones (90 – 120°C). The structural discordance between strongly affected overlying sequence and undeformed footwall sequence is typical for thrust faults. These data allow to interpret post-Lutetian stacking of backthrusts, it means before the Sub-Tatra group of the Central Carpathian Paleogene Basin (CCPB). This is also indicated by discordance between Lutetian and Priabonian-Oligocene sequences in northern part of the Turiec Basin.

In the Orava Highlands the backthrust zones along the Pieniny Klippen Belt (PKB) are accommodated by tectono-sedimentary mélanges (Záskalie Beds). The Záskalie Beds comprises of disrupted strata of Upper Cretaceous and Paleocene sediments with block-in-matrix fabrics. Large-sized blocks are represented by lithoclasts, detached slumps and broken beds, embedded in shaly matrix. The Záskalie Beds represent a syntectonic accumulation derived from the PKB units, southwardly thrusted over the footwall unit of the Oligocene flysch formations of the CCPB. This overthrust structure of the Upper Cretaceous – Paleocene deposits of the PKB is also visible after a recent landslide on a well-known locality in the Záskalie Beds, near Dolný Kubín. The primarly northvergent nappe structure of the youngest synsedimentary formations of the PKB was clearly overprinted by southvergent backthrusting, which is verified by shear deformation elements, strata in overturned position and dipping of the beds to the north. The backthrusting in the marginal mountain belt imply an important role of backstop orogenic wedging of the Western Carpathians.

Acknowledgements: The research was supported by projects of the Slovak Research and Development Agency (APVV-17-0170; APVV-20-0079) and Grant Agency for Science, Slovakia (VEGA 2/0013/20).

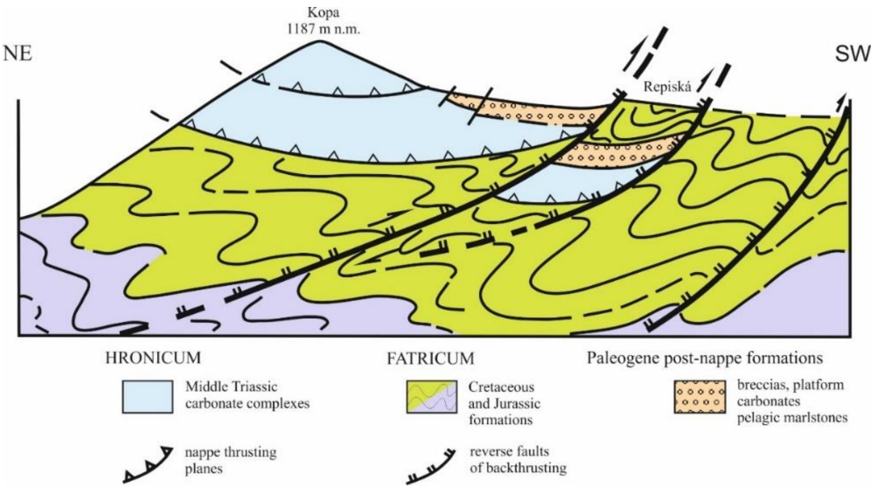


Figure 1: Reverse faults in the Kopa hill of the Veľká Fatra Mts. formed by backthrusting of Lower Cretaceous formations of the Krížna units over the Paleogene cover sediments.

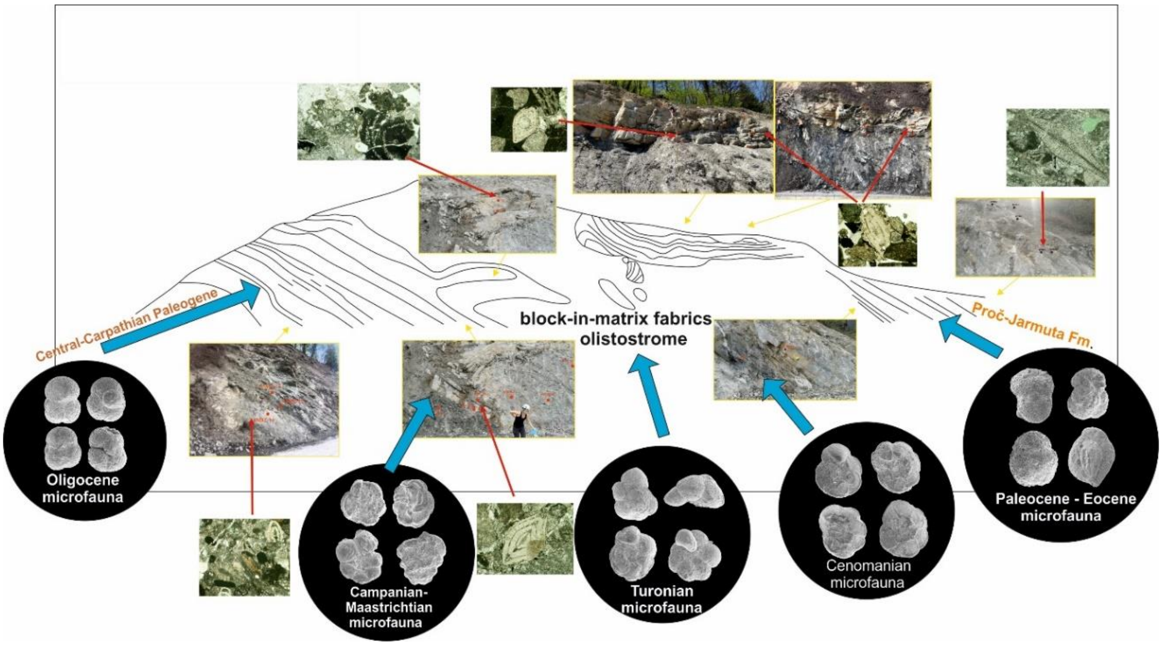


Figure 2: Shear zone with block-in-matrix structure formed by south-vergent backthrusting of the Pieniny Klipen Belt units above the Central-Carpathian Paleogene formations. A mélange derived from different Upper Cretaceous formations (Záskalie breccia) is covered by the Proč-Jarmuta beds and thrusted over the Oligocene flysch-type formations.

Tracing of greenhouse-icehouse transition in the Paratethyan basins: a case study from the turbiditic sequences of the Central-Carpathian Paleogene basin

JÁN SOTÁK[1,2] and FRANTIŠEK TEŤÁK[3]

1 – The Earth Science Institute of the Slovak Academy of Sciences, Ďumbierska 1, 974 11, Banská Bystrica Slovak Republic; e-mail: sotak@savbb.sk

2 – Faculty of Education, Catholic University in Ružomberok, Hrabovská cesta 1, 03 401 Ružomberok, Slovak Republic

3 – State Geological Institute of Dionýz Štúr, Mlynská dolina 1, 817 04 Bratislava, Slovak Republic

A high-quality reference section near Istebné in the Orava region has been studied for providing a depositional stacking of turbiditic-hemipelagic (mega) cycles, detailed foraminiferal and nannofossil microbiostratigraphy, geochemical proxies and another changes related to the Eocene/Oligocene boundary. The section of about 220 m thick consists of turbidites, hemipelagic marls and deep-water claystones. The lower sequence is formed by muddy turbidites with interbeds of upper Bouma seqences Tc-Td (rippled and laminated sandstones), which higher-up developed thicker turbidite megabeds (2.5 – 4.0 m) with submarine slumps and complete Ta – Te Bouma sequences. This trend reflects a thickening upward turbidite sequences towards to the Eocene/Oligocene boundary (EOT), which indicate a global sea-level fall at that time (Miller et al. 2009). Lowstand conditions around the EOT is documented by thick bioclastic beds accumulated by erosion of bryozoan-rich carbonate platforms.

The Eocene sequence dominates by non-calcareous claystones with deep-water agglutinated microfauna like foraminifera *Reophax pilulifer*, *Rhabdammina cylindrica*, *Ammodiscus cretaceous*, *Glomospira charoides*, etc.. Hemipelagic interval contains a rich planktonic foraminifera, which belong to index species of late Eocene, like *Hantkenina alabamensis*, *Globigerinatheka index*, *Turborotalia cerroazulensis*, *Subotina linaperta*, *Catapsydrax unicavus*, etc. (cf. Coccioni 1988, Premoli Silva and Jenkins 1993; Pearson et al. 2008). Last occurrences of these species marked the Eocene/Oligocene boundary around 120 m in the Istebné section. Proximity of the Eocene/Oligocene boundary is also constrained by tuffite layer, which correspond to "Tuff 25" dated around 32.8 – 34.6 Ma in the Carpathians (*sensu* Van Couvering et al. 1981). This tuffite layer contains plenty of apatite grains, which indicate alkaline basic syngenetic volcanism.

Above the Eocene/Oligocene boundary, the sequence considerably changes by dwarfing of microfauna and appearance of new foraminiferal species. A high density of minute foraminifers implies an increase of productivity due to eutrophication, climatic cooling and/or upwelling. Majority of foraminifers became dominant by small-sized opportunistic species like *Globigerina* (*bulloides – officinalis* plexus), *Tenuitella* and *Chiloguembelina*, which are associated with species of *Dentoglobigerina* (*D. tapuriensis*, *D. venezuelana*, *D. galavisi*), *Paragloborotalia* and *Turborotalia* (*P. nana*, *T. ampliapertura*), *Globoturborotalita* (*G. ouachitaensis*, *G. martini*), and others.

Lower Oligocene sequence reveals a pronounced change, passing to dark shales of the Menilite-type formation. Euxinic conditions resulted in poor planktonic microfauna of minute globigerinids, benthic agglutinated foraminifers still proliferated due to increase supply of organic carbon. Beside of microfauna, the residues derived from Menilite shales are rich in fish remains and phosphates. Menilite shales are intercalated by tuffite layer (38 cm) with a distinct concentration of apatite and leucoxene. This tuffite layer can correspond to "Tuff 26" from lower Menilite beds of the Carpathians (*sensu* Van Couvering et al. 1981). The Lower Oligocene sequence grades upward to horizons of Menilite cherts, which imply a stepwise cooling, eutrophication and biosiliceous productivity.

Acknowledgement: The study was supported by the projects APVV-20-0079 and VEGA 2/0013/20.

References:

Coccioni, R. 1988. The genera *Hantkenina* and *Cribrohantkenina* (foraminifera) in the Massignano section (Ancona, Italy). In: Premoli Silva I. et al. (Eds.): The Eocene-Oligocene boundary in the Marche-Umbria basin (Italy). *Ancona*, 81–96.

Miller, K., Wright, J.D., Katz, M.E., Wade, B.S., Browning, J.V., Cramer, B.S. & Rosenthal, Y. 2009. Climate threshold at the Eocene-Oligocene transition: Antarctic ice sheet influence on ocean circulation. Koeberl, C. & Montanari, A. (Eds.): The Late Eocene Earth. *GSA Special paper*, 452, 1–10.

Pearson, P.N., McMillan, I.K., Wade, B.S., Dunkley Jones, T., Coxall, H.K., Bown, P.R. & Lear, C.H. 2008. Extinction and environmental change across the Eocene-Oligocene boundary in Tanzania. *Geology*, 36, 2, 179–182.

Premoli Silva, I. & Jenkins, D.G. 1993. Decision on the Eocene-Oligocene boundary stratotype. *Episodes*, 16, 379–382.

Van Couvering, J.A., Aubry, M-P., Berggren, W.A., Bujak, C.W., Naeser, C.W. & Wieser, T. 1981. The Terminal Eocene Event and the Polish connection. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 36, 321–362.

Cretaceous/Paleogene boundary events in the Western Carpathians: proxy record of biotic crisis, recoveries, environments and sea-level changes

JÁN SOTÁK[1,2], TIIU ELBRA[3], PETR PRUNER[3], SILVIA ANTOLÍKOVÁ[1], PETR SCHNABL[3] and ŠIMON KDÝR[3]

1 – Earth Science Institute, Slovak Academy of Sciences, Ďumbierska 1, 974 11 Banská Bystrica, Slovak Republic; e-mail: sotak@savbb.sk

2 – Faculty of Education, Catholic University in Ružomberok, Hrabovská cesta 1, 03 401 Ružomberok, Slovak Republic

3 – The Czech Academy of Sciences, Institute of Geology, Rozvojová 269, 165 00 Prague, Czech Republic Earth Science Institute, Slovak Academy of Sciences, Dúbravská cesta 9, 840 05 Bratislava, Slovak Republic

Cretaceous/Paleogene boundary events of the Alpine Tethys were considerably upgraded for the Western Carpathians. The reference section near Kršteňany provides high-resolution data from the Cretaceous-Paleogene (K/Pg) transition to Lutetian/Bartonian boundary. The Upper Cretaceous sequence started from terrestrial red-beds superposed by transgressive sediments with *Abathomphalus mayaroensis*. The K/Pg transition is inferred in a horizon with reworked Maastrichtian microfossils and earliest Danian species of Globigerinidae. Multiple redeposition with *eugubina*-rich clasts implies a storm erosion and resuspension of the post K/Pg sequence during P0 – Pα Zones (approx. 300 kyr). Beside of abrupt biotic changes, the K/Pg boundary in the Žilina section is also marked by elevated Hg concentrations. The early Danian microfauna was initially impoverished, later enriched by first praemuricids, and after the Latest Danian Event (LDE) diversified to angulate morozovellids, igorinids and fasciculiths. Paleocene bioevents and polarity chrons imply a radiation of planktic foraminifera during transgressive cycles in the late Danian (P1, C28n), Middle Selandian (P3b, C26r/n) and late Thanetian (P4c/P5, C25n/C24r), and vacant P/C zones either in regressive cycles or during unconformities in the early Danian (P1a/C28r), Danian/Selandian transition (P2/P3a, C27r/n) and middle Thanetian (P4b/C25r). The late Thanetian transgression (Th-2) led to replacement of *Assilina*-rich beds (SBZ 4) by Nummulites-bearing marls (SBZ 5) at the base of Illerdian (= LFT). The Paleocene – Eocene transition is marked by *Acarinina*-rich marlstones with densely muricate species (*Ac. acarinata*) and excursion taxa (*Ac. sibaiyaensis*, *D. araneus*), which correspond to the Paleocene-Eocene Thermal Maximum (PETM). This horizon implies a warm-water productivity, eutrophication, humidity and upwelling activity (pteropods, diatoms). The hyperthermal conditions culminated at the beginning of the Early Eocene Climatic Optimum (EECO) with demise of morozovellids, intensification of hydrological cycles and enhanced continental input of siliciclastics, which progressed by accumulation of Ypresian nummulite banks and terminated by pelagic deposition with recovery of hispid morozovellids (E5 – E7 Zones, chron C23n – C22r). The lower Lutetian sequence reveals a post-EECO cooling by predominance of deep-dwelling habitats (subbotinids, turborotaliids, catapsydracids) and appearance of subtile morozovellids (*M. gorrondatxensis*), earliest globigerinathekids and another marker species of the E7 – E8 Zones (chron 22n – C21r). Late Lutetian warming (LLTM) is indicated by increased plankton productivity of mixed-layer habitats like strongly muricate species of anguloconical acarininids (*Ac. topilensis*, *Ac. medizzai*) and gracile species of morozovelloids (*M. coronatus*). The youngest part of the Kršteňany section belongs to the E11 Zone, indicating prior conditions of Middle Eocene Climatic Optimum (MECO) warming.

Acknowledgements: The research was supported by projects of the Slovak Research and Development Agency (APVV-17-0170), Grant Agency for Science, Slovakia (VEGA 2/0013/20) and the Czech Science Foundation, project no.19-07516S acc. research plan no RVO67985831.

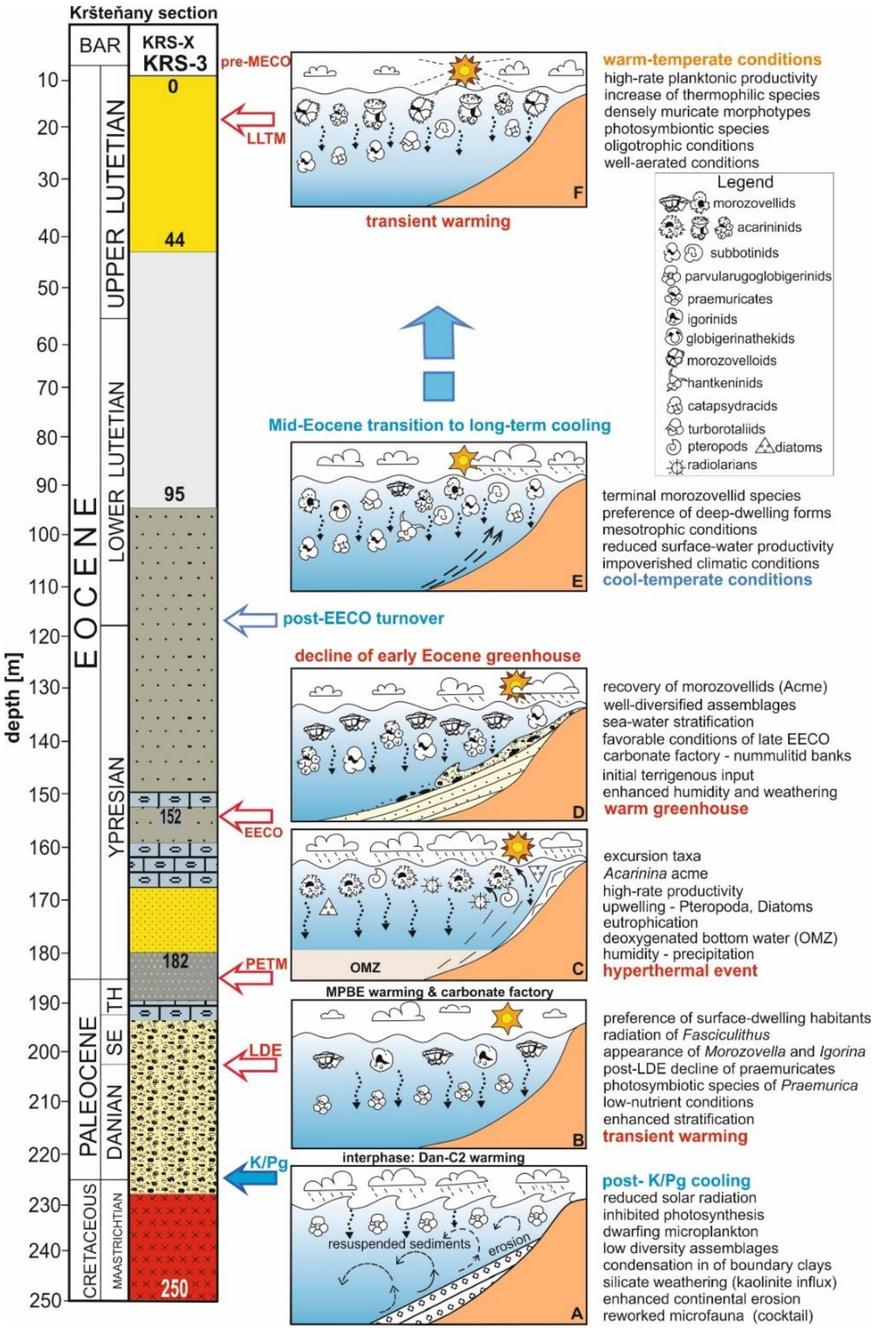


Figure 1: Cartoons illustrating biotic, climatic and environmental changes derived from Kršteňany section, and related to end-Cretaceous to middle Eocene events (K/Pg, LDE, PETM, EECO, LLTM).

A multiproxy study reveals spatial and temporal changes in paleoenvironments from demise of the Sarmatian Sea to the Lake Pannon flooding, central Vienna Basin, Slovakia

MICHAL ŠUJAN[1], ĽUBOMÍR SLIVA[2], KATARÍNA ŠARINOVÁ[3], RÉGIS BRAUCHER[4], OLEG MANDIC[5], ANDREJ CHYBA[6], NATÁLIA HUDÁČKOVÁ[1], MICHAL JAMRICH[1], MARIANNA KOVÁČOVÁ[1], MATHIAS HARZHAUSER[5], NADJA OGNJANOVA-RUMENOVA[7], KISHAN AHERWAR[1], ASTER TEAM[5] and MICHAL KOVÁČ[1]

1 – Department of Geology and Paleontology, Faculty of Natural Sciences, Comenius University in Bratislava, Ilkovičova 6, 842 15 Bratislava, Slovak Republic; e-mail: michal.sujan@uniba.sk

2 – NAFTA a.s., 900 68 Plavecký Štvrtok 900, Slovak Republic

3 – Department of Mineralogy, Petrology and Economic Geology, Faculty of Natural Sciences, Comenius University in Bratislava, Ilkovičova 6, 842 15 Bratislava, Slovak Republic

4 – CNRS-IRD-Collège de France-INRA, CEREGE, Aix-Marseille Univ., 13545 Aix-en-Provence, France

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

6 – Institute of Chemistry, Slovak Academy of Sciences, Dúbravská cesta 9, 845 38 Bratislava, Slovak Republic

7 – Department of Paleontology, Stratigraphy and Sedimentology, Institute of Geology, Bulgarian Academy of Science, Acad. G. Bonchev str. 24, 1113, Sofia, Bulgaria

The replacement of diverse environments of the Sarmatian Sea by isolated Lake Pannon at the Middle/Late Miocene transition represents a major paleogeographic and paleoenvironmental change in the Central Europe (Magyar et al. 1999; Harzhauser & Mandic 2008). This study aims to trace this transition in the central Vienna Basin, Slovakia, by the use of sedimentology, reflection seismics and well logs, geochemistry, biostratigraphy and authigenic ^{10}Be/^{9}Be dating. The analysis was focused on cores of the Gajary borehole series, taken from the uppermost Sarmatian unit, and the lowermost two Pannonian units, identified in petroleum prospection routine as 1st Sarmatian, 8th Pannonian and 7th Pannonian.

The seismic survey revealed an undulated erosional unconformity on the base of the Pannonian strata, dividing low amplitude reflectors below from pronounced high amplitude reflectors above. The Sarmatian strata situated just below the unconformity exhibit significant variability from offshore facies with high bioturbation intensity, frequent mollusks (e.g., *Sarmatimactra eichwaldi*, *Inaequicostates politioanei*, *Granulolabium bicinctum*) and abundant plant detritus, to cross-stratified sandy strata deposited by waves and/or unidirectional traction currents. The calcareous nannoplankton species also implied the Sarmatian age of the cores. The high amplitude reflectors of the 8th Pannonian consist of spatially diverse, mostly sandy facies. Proximal deposits include cross-stratified sandy strata deposited by unidirectional traction currents and occurrence of storm-wave facies with liquefaction, and are deposited above a supposed incised channel. The Pannonian age is proved by the presence of the nannoplankton species *Isolithus semenenko* and *Lymnocardium* shells. The horizon of 8th Pannonian thins out from ca. 70 ms in its proximal part to 30 ms in its distal portion, where it consists of bioturbated, poorly laminated offshore muds.

The spatial variability of the 8th Pannonian contrasts with monotonous offshore muds forming lower part of the 7th Pannonian unit, appearing in all studied cores. These low amplitude reflectors are overlain by up to 130 ms thick clinoforms, implying an event of flooding followed by a delta slope progradation. Upward fining few cm thick, muddy strata with inclination of 10 – 12° likely represent gravity current deposits associated to the deltaic slope.

The described changes in depositional processes correspond to the sediment composition. Facies of 1st Sarmatian and 8th Pannonian are composed of fine-grained calcareous mudstones. When considering the redox and salinity proxies (Fe-S-TOC patterns, enrichment factor of U, Ni, Co), the Sarmatian samples were formed in variable, oxic to dysoxic conditions with probable freshwater input, while the 8th Pannonian shifted to dysoxic conditions connected to the precipitation of carbonates. Foraminifera shows shift from a typical shallow euryhaline water associations (*Sinuloculina consobrina*, *Haynesina depressula and Ammonia tepida*) in the 1st Sarmatian to an extremely low diversified marsh association tolerating oxyc stress in the Pannonian, dominated by *Miliammina* sp. together with algae species of *Tasmanites* genus. Lowermost Pannonian monoassociation of *Trochammina kiblery* contain reworked Lower Miocene forms, e.g., *Cassigerinella boudecensis* and *Bolivina hebes*. The Trochammina association is supplemented upwards by specimens from *Miliammina* and *Saccammina* genera. Both associations survive shallow water dysoxic conditions. The flooding of the 7th Pannonian is mirrored by input of coarser mud, lower carbonate admixture and recovery of the oxic/dysoxic conditions with presumable freshwater inflow. It includes a significantly increased nutrient supply causing diatom blooms with high abundance of *Actinoptychus senarius* and *Aulacoseira ambigu*a.

The authigenic $^{10}Be/^{9}Be$ dating results of 23 samples exhibit very low variability, albeit the sampled cores represent different environments of various sediment source proximity. The weighted mean ages for the 7th and 8th Pannonian are almost identical within the error bars, reaching 10.84 ± 0.16 Ma and 10.83 ± 0.17 Ma, respectively. The 1st Sarmatian unit yielded higher weighted mean age of 11.19 ± 0.25 Ma, however, this age is younger than 11.6 Ma (Middle/Late Miocene boundary), pointing to a possible shift of the initial $^{10}Be/^{9}Be$ ratio in the shallowing and disappearing Sarmatian Sea. The results indicate that either (1) a period of subaerial exposure ~0.8 Myr long appeared between the regression and the following flooding, (2) a very condensed deposition appeared during this period, or (3) the earliest Pannonian strata were eroded before the deposition of the studied 8th Pannonian unit.

Acknowledgement: The study was supported by the Slovak Research and Development Agency (SRDA/APVV) under contract No. APVV-16-0121 and APVV-20-0120. Our gratitude goes to the Nafta company management for allowing access to well core repository and to the geophysical data.

References:

Harzhauser, M. & Mandic, O. 2008. Neogene lake systems of Central and South-Eastern Europe: Faunal diversity, gradients and interrelations. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 260, 417–434.

Magyar, I., Geary, D.H. & Müller, P. 1999. Paleogeographic evolution of the Late Miocene Lake Pannon in Central Europe. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 147, 151–167.

Tithonian–Berriasian boundary: biostratigraphy, stable isotopes and paleomagnetism in the Silesian Unit, Western Carpathians

LILIAN ŠVÁBENICKÁ[1], ANDREA SVOBODOVÁ[2], DANIELA REHÁKOVÁ[3], MIROSLAV BUBÍK[4], PETR SKUPIEN[5], LUCIE VAŇKOVÁ[6], MARTIN KOŠŤÁK[6], TIIU ELBRA[2], PETR PRUNER[2], JAN GEIST[6] and MARTIN MAZUCH[6]

1 – Czech Geological Survey, CZ-118 21 Praha, Klárov 131/3, Czech Republic; e-mail: lilian.svabenicka@geology.cz

2 – Czech Academy of Sciences, Institute of Geology, Rozvojová 269, CZ-165 00 Praha, Czech Republic

3 – Comenius University, Faculty of Natural Sciences, Ilkovičova 6, SK-842 15 Bratislava, Slovak Republic

4 – Czech Geological Survey, Leitnerova 22, CZ-658 69 Brno, Czech Republic

5 – Technical University of Ostrava, Institute of Geological Engineering, 17. listopadu 15, CZ-708 33 Ostrava-Poruba, Czech Republic

6 – Charles University, Faculty of Sciences, Albertov 6, CZ-128 43 Praha, Czech Republic

Multidisciplinary research of the Tithonian-Berriasian boundary was carried out at the Ropice Section near Český Těšín, Czech Republic. It was studied in the framework of a worldwide effort for selecting the boundary criteria and potential GSSP candidates for the Berriasian Stage. Data from Ropice thus contribute to interregional correlations with other sections in the Alpine–Western Carpathian domain: Štramberk, Kurovice, Golubac, Rettenbacher, Tré Maroua, Sněžnice, Brodno, and Strapková (Michalík et al. 2021).

The strata of the Ropice belong to the Těšín Limestone of the Silesian Nappe Unit, Outer Flysch Carpathians. The boundary interval comprises light grey turbiditic limestones (grainstones, packstones and wackestones) interbedded with grey marlstones (mudstones). The limestones contain calpionellids, calcareous foraminifers, and calcareous dinoflagellate cysts. The mudstones provide calcareous nannofossils, siliceous agglutinated foraminifers, and organic-walled dinocysts. The lowermost Berriasian is determined based on the co-occurrence of *Nannoconus wintereri* and acme *Calpionella alpina.* The weak $\delta^{13}C$ signal is here similar to the majority of the Outer Flysch Carpathian sections (Vaňková et al. 2019). The highest paleomagnetic susceptibility 143 E-6 SI was found just in the underlying bed of these events.

Calpionellids are relativelly well preserved. Microfacies analysis confirmed the presence of index markers on the base of which several standard calpionellid zones and subzones were documented sensu (Reháková and Michalík 1997): uppermost Early Tithonian Chitinoidella Zone (Boneti Subzone), Late Tithonian Crassicollaria Zone (Remanei, Intermedia and Colomi subzones) and Early Berriasian Calpionella Zone (Alpina Subzone). The JK boundary has been traced in the interval around the bed 16 in which globular variety of *Calpionella alpina* are dominated in biomicrite wackestones to mudstones (Wimbledon 2017). The onset of the Alpina subzone correlates well with results given by Early Berriasian nannofossils marker *N. wintereri* mentioned above.

Nannofossils are mostly etched across the section. Characteristic is abundance of genera *Watznaueria* (±76 %) and *Cyclagelosphaera* (±19 %) forming the main component of assemblage. Stratigraphically important nannoconids, *Polycostella beckmannii*, *Helenea* *chiastia* and *Cruciellipsis cuvillieri* were found rarely. The FO of *Nannoconus wintereri* confirms the NC0a Subzone (Casellato and Erba 2021).

Dinoflagellate cyst association with *Mendicodinium groenlandicum, Systematophora areolate* and *Systematophora orbifera* of late Tithonian age occurs in the lower part of the section. Presence of *Amphorula delicata, Muderongia longicorna* and *M. tabulata* correlate well with the lowermost Berriasian Alpina Subzone.

Small calcareous foraminifera (Spirillina, Trocholina, Lenticulina) and agglutinated foraminifera (Pseudoreophax cisovnicensis, Pseudonodosinella troyeri, Ammogloborotalia quinqueloba, Caudammina silesica) are rather of low biostratigraphic value.

The stable isotopic record ($\delta^{18}O$, $\delta^{13}C$) shows mostly lower positive values of the $\delta^{13}C$ (~0.5 ‰, PDB) with also several negative expressions reaching (~ -1.7 ‰, PDB), and typical negative values of the $\delta^{18}O$ (~ -4.2 ‰, PDB). The weak $\delta^{13}C$ signal is consistent with the majority of the Outer Flysch Carpathian sections in the J/K boundary interval.

Magnetic data indicate an extensive remagnetization, with the presence of weathering product goethite, along whole section. Average magnetic susceptibility and natural remanent magnetization show low values, 48 E-6 SI and 0.17 mA/m, respectively. The highest susceptibility (143 E-6 SI) was found in bed 15.

Acknowledgement: The research is supported by the Czech Science Foundation project no. 20-10035S, and it is contribution to research plans no. RVO67985831 and DRKVO/ČGS 2018–2022. Microfacies, calpionellid and calcareous dinocyst investigations is founded by the project of the Slovak Grant Agency no. APVV-20-0079 and by VEGA 2/0013/20.

References:

Casellato, C.E. & Erba, E. 2021. Reliability of calcareous nannofossil events in the Tithonian-early Berriasian time interval: Implications for a revised high resolution zonation. *Cretaceous Research* 117, Art. no. 104611.

Michalík, J., Grabowski, J., Lintnerová, O., Reháková, D., Kdýr, Š. & Schnabl, P. 2021. Jurassic–Cretaceous boundary record in Carpathian sedimentary sequences. *Cretaceous Research* 118, Art. no. 104659.

Reháková, D. & Michalík, J. **1997.** Evolution and distribution of calpionellids – the most characteristic constituents of Lower Cretaceous Tethyan microplankton. *Cretaceous Research*, 18, 493–504.

Vaňková, L, Elbra, T., Pruner, P., Vašíček, Z., Skupien, P., Reháková, D., Schnabl, P., Košťák, M., Švábenická, L., Svobodová, A., Bubík. M., Mazuch, M., Čížková, K. & Kdýr, Š. 2019. Integrated stratigraphy and palaeoenvironment of the Berriasian peri-reefal limestones at Štramberk (Outer Western Carpathians, Czech Republic). *Palaeogeography, Palaeoclimatology, Palaeoecology*, 532, 109256.

Wimbledon, W.A.P 2017. Developments with fixing a Tithonian/Berriasian (J/K) boundary. *Volumina Jurassica* 15, 181–186.

Milestones in understanding Lake Pannon depositional systems

ORSOLYA SZTANÓ

ELTE Institute of Geography and Earth Sciences, Department of Geology, Budapest, Hungary; e-mail: sztano.orsolya@gmail.com

During the 19th – 20th century knowledge on the Late Miocene – Pliocene depositional environments within Lake Pannon were gained mostly by palaeontological studies, depicting various shallow and much later some deep-water biotops. The first application of modern sedimentology was the reconstruction of the delta environment and its cyclic repetition from hundreds of wells at the Algyő gas field. It was followed by recognition of turbidite systems in some key wells from the deepest parts of the basin. At the same time, the six major depositional units and the corresponding lithostratigraphic ones were also defined, mainly with the integration of seismic stratigraphy. However, the recognition of several hundred-meters high clinoforms also led to a misunderstanding of the depositional dynamics hindering further understanding for more than two decades. Moreover, information from outcrops and shallow wells mostly from the outskirts of hilly areas was not combined into the big picture gained from the subsurface data of deep basins.

In the last decades one the most important steps were distinction of locally derived deltas formed during early transgressive events and those deltas that were supplied from distal Alpine-Carpathian provenances during the long-term normal regression of Lake Pannon. It was important to realize that this latter can be studied in detail in outcrops along the uplifted margins of the hills and not only as cores of the deep basins. With other words, the basin-fill was a rather uniform process taking place above a highly differentiated lake floor topography: the same type of delta lobes appeared repeatedly above shallow basement highs and the filled-up deep-basin portions due to climate-driven lake-level fluctuations. Development of high and ultra-high resolution seismic visualized the delta-scale clinoforms. It was emphasized that deltas develop on shelves and thus highlighted that shelf-slope scale clinoforms cannot be mistaken with the deltaic ones.

The modern sedimentology also helped to understand the deep-water systems. Appearance of sediment gravity flow deposits within the oldest calcareous marl beds indicate an early and very rapid deepening of the lacustrine system, while they also point to the presence of islands nearby. Cessation of mass transport revealed gradual flooding of the subaerially exposed areas. It was also important to explore that the development of the large-volume, distally-sourced turbidite systems were highly influenced by lake-floor topography, with strong confinement in some isolated basin centers. Accumulations in upstream and down-stream basins showed not only temporal differences but variation of sand/mud ratios due to fill-and spill effects, unless tortuous corridors developed. Recognition of Hybrid Event Beds (HEBs) promoted characterization of various turbidite systems. The slope related unconfined ones reflect the evolution of the aggradational to progradational shelf-slope and revealed that there was high rate of sand delivery to deep basins during climatically-induced lake-level rises, thus sequence stratigraphy must be applied with utmost care only as an analytical tool. The further analysis of controlling factors pinpointed a markedly different mechanism in long-term evolution of accommodation in endorheic lakes.

Sedimentological investigations were also fruitful in understanding the fluvial systems, feeding the lake. Based on field studies and analysis of well data various types of channel systems were recognized that additionally revealed either synsedimentary structural movements or climatic changes. As in case of turbidite or deltaic systems, application of 3D seismic geomorphology was essential to extend our knowledge on transport directions, distribution of geobodies related either to meandering or anastomosing systems, their spacial to temporal evolution.

Bits and chips of modern process-based sedimentological investigations in all countries of the Pannonian Basin became milestones only with integration of paleoecology, structural geology, and seismic-scale mapping of the “lake-scape”. Thus, promoting the understanding of the basin-fill architecture and the perpetual changes influencing the depositional systems of Lake Pannon.

Acknowledgement: I am grateful to the organizers of the 12th ESSEWECA meeting for the invitation that inspired this summary. Many studies were supported by projects of NRDIO no. 037724, 81530 and 112260.

The connection between the Alps and the Carpathians beneath the Pannonian Basin: a case for negative structural inversion

GÁBOR TARI[1], GÁBOR BADA[2], JÁNOS CSIZMEG[3], MICHAL KOVAČ[4], DUŠAN PLAŠIENKA[4] and MICHAL ŠUJAN[4]

1 – OMV Upstream, Vienna, Austria; e-mail: gabor.tari@omv.com

2 – TDE Services, Budapest, Hungary

3 – consultant, Budapest, Hungary

4 – Department of Geology and Paleontology, Faculty of Natural Sciences, Comenius University, Bratislava, Slovak Republic

The Cretaceous basement of the broader NW Pannonian Basin, including the Vienna Basin, has an Alpine nappe structure that can be correlated between the Eastern Alps and the Western Carpathians. Based on the systematic integration of petroleum industry vintage 2D reflection seismic data with well data from Austria, Hungary and Slovakia, we document various modes of interaction between pre-existing Alpine overthrust and superimposed normal faults. Whereas in some cases the pre-existing Cretaceous nappe contacts became extensional low-angle normal faults, the typical scenario is that the Miocene normal faults obliquely cut across them. The style of this negative inversion, i.e. contraction followed by extension exploiting the same fault system, is based on the orientation and geometry of the Alpine nappes in relation to the successor extensional basins. We expand our earlier findings made in the Hungarian sector of the NW Pannonian Basin where Neoalpine (Neogene) low-angle normal faults did indeed interact with abandoned Eoalpine (Cretaceous) and Mesoalpine (Paleogene) thrust fault planes, but in a more selective manner than expected before. The subsurface examples of this contribution are located in the Austrian part of the Vienna Basin, the Hungarian, Austrian and Slovakian segments of the broader Danube Basin. Our regional and local scale subsurface observations also helped to define a very large, but so far unrecognized Eocene antiformal nappe stack beneath the Danube Basin. Presently this Danubius Antiform is a highly dismembered and dominantly subsurface structure concealed beneath the NW Pannonian Basin between the Eastern Alps and the Western Carpathians. This finding has important implications for the understanding of the Alpine evolution of the broader region.

The transition zone between the Alps and the Carpathians, largely covered up by the Vienna and Danube Basins of the *sensu lato* Pannonian Basin system, provides an ideal region to study the reactivation of pre-existing contractional structural elements during subsequent extension. Using exceptionally large amount of industry and academic, legacy and modern 2D and 3D reflection seismic data acquired in the last five decades combined with a large amount of well data, various styles and extent of reactivation were documented. Contrary to the expectations, extensional reactivation, in a negative inversion sense, is a very selective process. In most of our case studies we found no evidence for this process to occur. Typically, Miocene normal faults in both the Danube and Vienna Basins did not exploit the Cretaceous and Paleogene Alpine thrust and nappe contacts immediately beneath the basin fill. However, towards deeper intra-basement levels, pre- existing thrust and subsequent low-angle normal fault planes many cases appear to merge into each other. Also, it is apparently much more difficult to make a convincing case for negative rather than positive structural inversion, especially when only subsurface data sets are available. Since the successor basin fill typically covers up all the surface evidence for the pre-existing fabric the spatial coincidence between the contractional and extensional structural elements can be proven beyond doubt only in exceptional cases.

In terms of structural geology, the same sense movement on any given fault plane occurs much more frequently compared to the cases when the sense reverses. Therefore, positive or negative structural inversions are regarded as special cases within the much more general process of fault reactivation. Extensional reactivation of former reverse faults or, specifically thrust planes in thrust fold belts, designated as "negative inversion", received much less attention by both the petroleum industry and the academia than the opposite process.

Based on the structural review of many case studies of positive and negative inversion they display contrasting kinematic patterns. One of the obvious structural differences is related to the geometry of short-cut structures developed during the more advanced stage of inversion. In the case of positive inversion, a short-cut thrust develops within the footwall of the major inverted fault to better accommodate the ongoing shortening. In contrast, a short-cut normal fault develops within the hanging wall of the partially inverted master fault during negative inversion. While the short-cut thrust associated with positive inversion typically does not produce traps, the short-cut extensional listric fault during negative inversion is trap-forming, both within its footwall and hanging wall.

In the border zone between Austria, Hungary and Slovenia, the Miocene opening of the Pannonian Basin was characterized by extreme, large-magnitude upper crustal extension accommodated along low-angle detachment faults. This case study is also an example of interpretation of less-than-ideal legacy 2D seismic data sets (30 – 50 year old) reproduced in variable formats (i.e. hard-copies scanned and georeferenced without reprocessing or even vectorization). From a structural geology perspective, the early interpretation of these vintage seismic profiles was done in the 1980s without the appreciation of the existence of low-angle normal faults and structural reactivation, in general. The reassessment of the same data sets used in this study definitely benefited from the knowledge gained on these special structural features by both the academia and the petroleum industry over the past 40 years.

Given the increasing focus on low-carbon geo-energy solutions, the broader region also needs a modern re-evaluation of the subsurface geo-energy potential which is not related to hydrocarbons.

Acknowledgement: This contribution is dedicated to the memory of Prof. Frank Horváth (1944 – 2018) who was not only the scientific mentor and but also a great friend of many of the co-authors of this paper.

Disarticulation rates and time averaging of Holocene bathyal brachiopods in the southern Adriatic Sea

ADAM TOMAŠOVÝCH[1], DIEGO A. GARCÍA-RAMOS[2], RAFAŁ NAWROT[3], JAMES H. NEBELSICK[4] and MARTIN ZUSCHIN[3]

1 – Earth Science Institute, Slovak Academy of Sciences, Bratislava, 84005, Slovak Republic; e-mail: geoltoma@savba.sk

2 – Università degli Studi di Ferrara, Dipartamento di Fisica e Scienze della Terra, Via Saragat 1,44122 - Ferrara, Italy

3 – Department of Palaeontology, University of Vienna, Althanstrasse 14, 1090 Vienna, Austria

4 – Department of Geosciences, University of Tübingen, Schnarrenbergstrasse 94-96, 72076, Tübingen, Germany

Carbonate skeletal remains (molluscs, brachiopods) tend to be damaged and disintegrate rapidly (at yearly to decadal scales) in Holocene shallow-marine environments, typically owing to intense bioerosion at the sediment-water interface and dissolution driven by organic matter decomposition within sediment. Present-day brachiopod death assemblages exposed on continental shelves in the taphonomically-active zone (upper cm of seabeds) are invariably characterized by poor preservation. Therefore, abundant articulated shells of brachiopods with complete internal support (brachidia) are not expected to be preserved if not rapidly buried. However, such paradoxical preservation (with high abundance of articulated shells in fossil assemblages) is frequently observed in shallow-water Paleozoic and Mesozoic brachiopod shell beds. Here, we document that a bathyal death assemblage (Bari Canyon, southern Adriatic Sea) surprisingly consists of high frequency of sediment-filled, well-preserved and articulated shells of the brachiopod *Gryphus vitreus* with complete brachidia. Frequency distributions of postmortem ages based on 92 specimens dated by radiocarbon show that (1) their time averaging is millennial (interquartile age range = 1,250 years) and (2) disintegration half-life of this brachiopod exceeds several centuries (~500 – 1,700 years). The high frequency of articulated but centuries-old shells (>50 %) and the fitting of taphonomic models to postmortem ages further indicate that disarticulation half-life is also long (~200 years). We hypothesize that rapid sediment filling of brachiopod shells (1) inhibited disarticulation and fragmentation of brachidia and (2) induced precipitation of ferromanganese coatings within shells. Sediment-filled articulated shells, however, still resided at the sediment-water interface as suggested by external encrusters and by sponges that bored into shells death of brachiopods. This pathway with slow disarticulation in Holocene bathyal environments might be an analogue of conditions leading to preservation of articulated shells in shallow-water (shelf) assemblages prior to the Mesozoic Marine Revolution.

Deinotheres (Proboscidea, Mammalia) of Slovakia: Biochronological overview

CSABA TÓTH

Earth Science Institute, Slovak Academy of Sciences, Dúbravská cesta 9, 840 05 Bratislava; e-mail: geoltoth@savba.sk

Deinotheres are an extinct side branch of the proboscideans. Their most outstanding features are the absence of upper tusks, down turned mandibular symphysis with conical short lower tusks and simple brachyodont-lophodont molars. In Europe, they were distributed from the Early to Late Miocene (Early Pliocene?). Although the morphology of deinothere teeth is conservative, the trend in size increase is frequently used for the biostratigraphic purposes. However, due to the complicated taxonomy, their overall biochronological interpretation is chaotic. Moreover, the different bioprovinces of Europe were probably not inhabited by the same deinothere taxa simultaneously. Here, we temporary prefer two cumulative European genera (*Prodeinotherium* and *Deinotherium*) and five species (*P. cuvieri, P. bavaricum, D. levius, D. giganteum*, and *D. proavum*).

Deinotheres are extremely rare in Slovakia. Only 12 localities (situated mainly in the Vienna and Danube basins) yielded their fossils. Unfortunately, some of them are known only from the literature with dubious stratigraphy. Complete revisory studies have made it possible to update our knowledge about the biochronology of deinotheres in the territory of Slovakia.

The oldest – Orleanian deinothere record in Slovakia is known from Veľký Krtíš and Dolné Plachtince (Tóth 2010 and unpublished material). Both sites are dated to Ottnangian (MN4), and are slightly younger than the first documented occurrence of deinotheres in Central Europe in Late Eggenburgian, MN3b (Gasparik 2001). The fossils are tentatively determined as *P. cuvieri*. However, the possible validity of *P. hungaricum* is not ruled out, which could indicate the presence of more than one Orleanian deinothere species in Europe. From the Karpatian (MN5) we do not know any deinothere remains from Slovakia.

A part of the Astaracian localities with confirmed occurrence of deinotheres is particularly well documented from the biostratigraphic point of view. Unfortunately, all remains are very fragmentary with a controversial taxonomy. The Early Badenian (lower part of MN6) locality Devínska Nová Ves – Štokeravská vápenka is one of the rare sites with a possible occurrence of two deinothere species (*P. bavaricum* and *D. levius*) (Zapfe 1954; Tóth 2010). Only *D. levius* have been documented in the slightly younger (upper part of MN6) locality Devínska Nová Ves – Sandberg (Thenius 1952). These remains could represent the earliest appearance of *D. levius* in Central Europe. The age of *P. bavaricum* tooth from Svinná is questionable (MN6 or early MN7/8).

Early Vallesian dramatic faunal changes, connected with the dispersion of new Hipparion fauna, did not affect the deinotheres in Slovakia and in other parts of Central Europe (contra Gasparik 2001, although he prefers a different taxonomic model). *D. levius* was still present and documented in Borský Svätý Jur (MN9). Together with the material collected from other localities of comparable age (for example Sopron, Hungary – Gasparik 2001, Aiglstorfer et al. 2014) they represent the last evidence of *D. levius.*

During the Late Vallesian (MN10) *D. levius* was replaced by *D. giganteum.* Thus, the association of *D. giganteum* and *Tetralophodon longirostris,* as a generally proposed biostratigraphic significant marker for the entire Vallesian, is questionable. It is limited only to its upper part (MN10) in Central Europe. Unfortunately, *D. giganteum* is poorly documented in Slovakia. An isolated tooth was found in Pezinok (MN10) (Holec 2005). Doubtful unpublished material originates from the South-Eastern Slovakia (Slovak karst region), but unfortunately exact finding circumstances are not available.

Due to the scarce Early and Middle Turolian large mammal localities, deinothere remains dated to MN11 – 12 are not known in Slovakia. Remains of *D. proavum* (syn. *D. gigantissimum)* were unearthed from Madunice (Musil 1959), which is correlated with the MN13 unit. This site represents the northernmost and westernmost European *Deinotherium* distribution in the Late Turolian. MN13 is the last period with the certain occurrence of deinotheres in Central Europe. Their survival in Eastern (Vislobokova & Sotnikova 2001) and Central Europe (Gasparik 2001) up to the Early Pliocene is uncertain based on the current evidence.

Acknowlegment: The author is kindly indebted to M. Sabol, U. Göhlich, M. Gasparik, J. Březina, M. Šujan, M. Onderka, I. Smetanová, K. Csicsay, J. Madarás and M. Kováč for valuable discussions and support.

References:

Aigslstorfer, M., Göhlich, U. B., Böhme, M. & Gross, M. 2014. A partial skeleton of *Deinotherium* (Proboscidea, Mammalia) from the late Middle Miocene Gratkorn locality (Austria). *Palaeobiodiversity and Palaeoenvironments,* 94, 49–70.

Gasparik, M. 2001. Neogene proboscidean remains from Hungary; an overview. *Fragmenta Palaeontologica Hungarica*, 19, 61–77.

Holec, P. 2005. *Deinotherium giganteum* Kaup (Proboscidea, Mammalia) of Pezinok brickyard pit (Pannonian). *Mineralia Slovaca*, 37, 551–554.

Musil, R. 1959. The first record of *Deinotherium gigantissimum* Stefanescu, 1892 in our territory. *Acta Musei Moraviae,* 44, 81–88.

Thenius, E. 1952. Die Säugetierfauna aus dem Torton von Neudorf an der March (ČSR). *Neues Jahrbuch für Geologie und Paläontologie*, Abhandlungen 96, 27–136.

Tóth, Cs. 2010. Paleoecology and diversity of Neogene proboscideans (Proboscidea, Mammalia) from the Slovak part of the Western Carpathians area depending on climatic changes and biotic interactions. *Mineralia Slovaca*, 42, 439–452.

Vislobokova, I. A. & Sotnikova, M. V. 2001. Pliocene faunas with Proboscideans of the Former Soviet Union. – In: Cavaretta, G. Gioia, P., Mussi, M., & Palombo, M. R., (Eds.): *The World of Elephants. Proceedings of the 1st International Congress*, Consiglio Nazionale delle Ricerche – Roma, 157–160.

Zapfe, H. 1954. Die Fauna der miozänen Spaltenfüllung von Neudorf a. d. March (ČSR). Proboscidea. *Sitzungsberichte Österreichische Akademie der Wissenschaften, Mathematisch-Naturwissenschaftliche Klasse,* Abteilung I, 163, 71–87.

Illite crystallinity as indicator of geological processes – three examples

PETER UHLÍK[1], ONDREJ PELECH[2], ENA TOPALOVIĆ[3],
DARKO TIBLJAŠ[3] and ĽUBICA PUŠKELOVÁ[4]

1 – Comenius University, Faculty of Natural Sciences, Department of Mineralogy, Petrology and Economic Geology, , Ilkovičova 6, Mlynská dolina 842 15 Bratislava, Slovak Republic; e-mail: peter.uhlik@uniba.sk

2 – State Geological Institute of Dionýz Štúr, Mlynská dolina 1, 817 04 Bratislava, Slovak Republic

3 – University of Zagreb, Faculty of Science, Department of Geology, Horvatovac 102B, 10000 Zagreb, Croatia

4 – Earth Science Institute of the Slovak Academy of Sciences, Dúbravská cesta 9, 840 05 Bratislava, Slovak Republic

The most widely used method of determining grade of transformation in metapelitic sequences is the XRD-based illite crystallinity technique, introduced by Kübler. Kübler index (KI) of illite crystallinity was used to define the anchizone and also defined the prograde limit of diagenesis and the initiation of the epizone. The illite crystallinity technique measures the width of the first basal reflection of dioctahedral illite-muscovite at a spacing of the 10 Å, at half-height above the background (in $\Delta°2\theta$; review in Merriman & Peacor 1999). The contribution will present examples of KI use in three different geological environments.

The first set of samples is from NW Croatia, previously considered to be non-metamorphosed. The analyses were performed on the Late Paleozoic black shales belonging to the northwesternmost part of the Internal Dinarides sampled in the Samobor-Žumberak Mountains and the Marija Gorica Hills, and on the Triassic (Upper Ladinian) carbonaceous dolomites belonging to the post-Variscan Alpine overstep sequences of the Tisia Mega-Unit found in the western part of the Papuk Mountain. A total of 7 rock samples, including 3 dolomite samples (two of them rich in organic carbon), were used to measure KI values. XRD analysis of the Late Paleozoic black shales shows a dominance of illite, accompanied by chlorite. The KI values obtained range from 0.33 to 0.36 $\Delta°2\theta$, indicating that the black shales underwent anchizonal thermal alteration. The clay minerals in carbonaceous dolomites are illite and kaolinite. The KI values of 0.79 and 0.84 $\Delta°2\theta$ indicate a diagenetic alteration.

The second set of samples from the eastern part of the Strážovské vrchy Mts. represents a more or less typical region of the core mountains of the Western Carpathians. Four siltstone-claystones and one limestone sample with admixture of siliciclastic compounds are from the cover sequences of Tatricum (from the Triassic to the Cretaceous age). Three of them, with major components of illite and chlorite in clay fraction, identified a high anchizone. Two of them contain mixed-layered illite-smectite that shows only late diagenetic thermal alteration. Lower thermal transformation could be caused by less affected of buried zones by younger tectonics. This set of samples was supplemented by a sample from overlying Fatricum. This sample was also identified as late diagenetic.

The third example is located in the Central Slovakia Volcanic Field on the inner side of the Carpathian arc. The samples are from the intermediate-sulphidation precious and base metal deposit Banská Hodruša at the Rozália mine that is hosted by the central zone of a Miocene andesite Štiavnica stratovolcano (Kubač et al. 2018; Koděra et al. 2019). The significant presence of illite has been used for determination of temperature conditions and character of fluid that formed wall-rock alterations. KI was used for the calculation of crystallisation temperatures using the data from the recent geothermal area in Taupo, New Zealand (Ji and Browne 2000). At least 50 measurements of KI were done. They show a temperature range from 255 to 315°C, which is in agreement with the data from the study of fluid inclusions within the Banská Hodruša epithermal deposit (Koděra et al. 2019).

Acknowledgement: This work was supported by the grants APVV-15-0083 and APVV-20-0358.

References:

Ji, J.F. & Browne, P.R.L. 2000. Relationship between illite crystallinity and temperature in active geothermal systems of New Zealand. *Clays and Clay Minerals*, 48, 1, 139–144.

Koděra, P., Kubač, A., Uhlík, P., Vojtko, R., Chovan, M., Lexa, J., Milovský, R., Laurent, O. & Fallick E.A. 2019. Fluid evolution and genesis of epithermal gold deposit hosted by a shear-zone: Banská Hodruša. *Proc 15th Biennial SGA Meeting*, 3, 1042–1045.

Kubač, A., Chovan, M., Koděra, P., Kyle, J.R., Žitňan, P., Lexa, J. & Vojtko, R. 2018. Mineralogy of the epithermal precious and base metal deposit Banská Hodruša at the Rozália Mine (Slovakia). *Mineralogy and Petrology*, 112, 5, 705–731.

Merriman, R.J. & Peacor, D.R. 1981. Very low-grade metapelites: mineralogy, microfabrics and measuring reaction progress. *In*: Frey, M, & Robinson, D. (Eds.): *Low-Grade Metamorphism. Blackwell Science Ltd, Oxford*, pp. 61–107.

Two glacial lakes and two different paleoecological paths during the Late Pleistocene and Holocene as reflected by diatoms (Tatra Mts., Slovakia)

MARINA VIDHYA[1], RADOVAN PIPÍK[1],
DUŠAN STAREK[2] and RASTISLAV MILOVSKÝ[1]

1 – Earth Science Institute, Slovak Academy of Sciences, Ďumbierska 1, 97401 Banská Bystrica, Slovak Republic; e-mail: vidya.maryselvam@gmail.com

2 – Earth Science Institute, Slovak Academy of Sciences, Dúbravská cesta 9, 84005 Bratislava, Slovak Republic

A sedimentary record of two glacial lakes Batizovské pleso (1,884 m a.s.l.; BAT) and Nižné Temnosmrečinské pleso (1,677 m a.s.l; NTP) are composed of varves, transitional homogenous or irregularly laminated silt, and gyttja. The lakes originated before 16,000 cal. yr BP and this initial stage was distinctive of low species richness, weak preservation of diatoms as a result of melting glacier. Both the lakes are situated on the granodioritic bedrock but had different paleoecological paths and diatom taxonomic composition since their origin in the late Pleistocene.

The NTP diatom assemblages reflect an alkaline, oligo-mesotrophic lake since its origin ~16,000 cal. yr BP. Only in this early stage, the planktonic community *Lindavia* dominated and had a peak in their occurrence. The varve deposition reflecting the presence of glacier terminated ~14,500 cal. yr BP and this event correlates with the onset of Meiendorf interstadial. Deposition changed to irregularly laminated silt with slight rise in organic content in which the alkaliphilous taxa attained their maximum in the Bølling and Allerød interstadials. The short stadial periods of Oldest and Older Dryas show increase in acidophilous and oligotrophic taxa like *Pinnularia sinistra*, *P. acoricola*, *Amphora eximia*, *Genkalia boreoalpina*, *Surirella helvetica*.

The onset of gyttja in NTP (~12,300 cal. yr BP) started sharply in the mid Younger Dryas and was accompanied by sharp decrease in the relative abundance of acidophilous, oligotrophic, and littoral diatoms. With onset of Holocene, gyttja registered a continual diversity increase of species with wider trophic tolerance like *Pseudostaurosira pseudoconstruens*, *Encyonema reichardtii*, and *Sellaphora laevissima*. These favourable conditions were interrupted by a sand input from 9,640 to 9,500 cal. yr BP which caused a decline in diatom diversity.

The BAT diatom assemblages document an acidic, eutrophic shallow lake from ~16,000 cal. yr BP until the Oldest Dryas. The nutrients released from melting glacier caused a significant occurrence of eutrophic *Gyrosigma acuminatum Hantzschia abundans*, *Navicula cincta*. Only in this period the planktonic community of *Aulacoseira* dominated, and had a peak in their occurrence.

A short lasting rise of diversity of meso-eutrophic and alkaliphilous species occurred from 14,700 to 14,600 cal. yr. BP suggesting the manifestation of a warmer period. However these species were rapidly replaced by eutrophic *Gyrosigma acuminatum* which dominated until the onset of Oldest Dryas about ~13,680 cal. yr. BP, when BAT changed to slightly acidic to circumneutral inhabiting diatom communities of wider trophic range.

The deposits of Oldest Dryas, Bølling, and Older Dryas registered fluctuations in pH and trophic state. The oligotrophic and acidophilous *Amphora eximia, Pinnularia acoricola, P. stomatophora* var. *irregularis* occurred in the stadial events and meso-eutrophic and alkaliphilous *S. venter, S. pinnata, Cymbopleura naviculiformis, Sellaphora pseudopupula,* dominated in the interstadial period. The warmer period of Allerød, marked complete deglaciation of the valley at ~13,300 cal. yr BP where the varve sedimentation changed to homogenous fine clastic with continual rise of organic matter until ~8,000 cal. yr BP. The lake in the Allerød had similar paleoecologic characteristics as the lake in Bølling.

The lake in the Younger Dryas was slightly acidic and oligotrophic as shown by the increased abundance of *Fragileria tenera, F. tenera* var. *nana, Stauroneis reichardtii, Genkalia boreoalpina.* The onset of Holocene led to prominent flourish of wider trophic tolerant *S. laevissima, S. disjuncta, G. elegantissium,* and aerophilic *Humidophila schmassmannii.*

Gradual decrease of oligo-eutrophic and alkalphilous *S. pinnata, Pseudostaurosira brevistriata, Psammothidium microscopicum, P. subanglica* marked the abrupt onset of cold 8.2-ka event which started about 8.4 ka.

About ~8,000 cal. yr BP, the sedimentation in BAT changed to organic gyttja deposition and with the end of 8.2-ka event, alkalphilous taxa reappeared. Species composition showed such fluctuations until ~6,800 cal. yr BP reflecting shorter paleoecological changes.

Acknowledgement: This work was financially supported by the projects APVV-15-0292, APVV-20-0358, and VEGA2/0163/21.

Structure and deformation pattern of the Bôrka thrust sheets and Gemeric cover sequence in the Slovenské rudohorie Mts.: insights from geometric and kinematic analyses

RASTISLAV VOJTKO[1], ALEXANDER LAČNÝ[1,2],
TOMÁŠ POTOČNÝ[1] and MARÍNA MOLČAN MATEJOVÁ[1]

1 – Comenius University, Faculty of Natural Sciences, Department of Geology and Paleontology, Ilkovičova 6, 842 15 Bratislava, Slovak Republic; e-mail: rastislav.vojtko@uniba.sk

2 – State Nature Conservancy of the Slovak Republic, Little Carpathians Protected Landscape Area, Štúrova 115, 900 01, Modra, Slovak Republic

Nappes discovered at the end of the 19th century are considered common geological structures in orogenic belts. Geological studies often refer to a “nappe theory” and the kinematics and vectors of nappe movement are a solvable topic. Two end-member types of nappes are commonly distinguished such as fold nappes corresponding to large-scale recumbent folds and thrust sheets corresponding to allochthonous sheets with prominent shear or thrust zones inside the nappe body. The internal zone of the Central Western Carpathians has an imbricated structure with thick-skinned units overlain by superficial nappes. The Upper Paleozoic – Mesozoic sedimentary sequences in the nappe position are located mainly on top of the thick-skinned Gemeric Unit formed by the Permian formations in the cover position. These rocks belong to the Meliata accretionary wedge, which is represented by the thrust sheets of the thinned continental margin, Permian siliciclastic deposits, Triassic limestones and blueschist facies metabasalts. This part of the Meliata wedge was affected by HP/LT metamorphism and traditionally it is referred to as the Bôrka nappe. This nappe is one of the key thrusts in the Western Carpathians to understand the nappe tectonics, which travelled onto LP/LT Gemeric thick-skinned tectonic unit. The Meliatic Unit s.s. is composed of the Jurassic mélange with huge olistostromes with blocks of various Triassic carbonate rocks, ophiolite- and blueschists-bearing rocks. The Jurassic mélange and the HP/LT metamorphosed rocks are tectonically overlain by the extensive Turnaic and structurally the highest Silicic nappe systems in the Central and Inner Western Carpathians.

Based on the structural analysis, spatial geometry, overprinting criteria, and metamorphic condition of secondary planar (foliations and cleavages or fold axial surfaces) and lineation (hinge lines or fold axes) structures indicate the presence of three main deformation events. The (Alpine deformation – AD_1) deformation is characterised by the phyllitic foliation, schistosity, and other complex anastomosing shear-band structures which evolved under simple shear kinematics indicating top-to-the-west tectonic transport in the absence of any pure shear component. In the Bôrka nappe, the Permian conglomerate is characterised by flattening fabric defined by domains that represent identifiable deformed objects – flattened pebbles. In contrast, the Permian conglomerates of the Gemeric Unit have not overcome the more pronounced flattening of the pebbles. The AD_1 structures are related to E – W shortening, which is interpreted as a sign of the subduction of the oceanic crust during the Late Jurassic closing of the Meliata Ocean. The younger direction of thrusting (AD_2) of the nappe system is top-to-the-north simple shearing and was determined at many places and is characterised by south dipping axial fold surfaces, schistosity, and asymmetric crenulation cleavages, and S-C shear bands indicating top-to-the-north thrusting. The structural record is present in both the Bôrka nappe and the Gemeric cover sequence; however, the Bôrka nappe is significantly more influenced by this deformation than the Gemeric Unit. This switch of the shortening is linked with a large-scale and heterogeneous reworking of the whole Meliata accretionary wedge and underlying Gemeric Unit. This deformation overprint is related to continent-continent collision during the mid-and early Late Cretaceous ("pre-Gosau" deformation event) and is responsible for the nappe stacking of the Meliata Mesozoic wedge and Gemeric crystalline basements. The last observed structures (AD_3) refer to the E–W shortening with the symmetric gentle to open fold with sub-vertical axial surfaces, spaced cleavages locally with few pronounced top-to-the-east asymmetries. However, the fabric planes or lines are spaced apart within the rock, irregular and the fabric is non-penetrative.

Acknowledgement: The study was supported financially by the Slovak Research and Development Agency (APVV) under contracts Nos. APVV-17-0170 and APVV-21-0281.

Biomarkers in the sediments of Tatra Mts. lakes recorded the changes in the Holocene vegetation cover

LUCIA ŽATKOVÁ, RASTISLAV MILOVSKÝ and RADOVAN PIPÍK

Earth Science Institute, Slovak Academy of Sciences, Ďumbierska 1, 974 11, Banská Bystrica, Slovak Republic; e-mail: zatkova@savbb.sk

Fossil lipids preserved in lacustrine sediments represent an archive of paleovegetation and paleoclimate evolution. In our running research, we apply an actualistic approach to such archives in Tatra Mts. and interpret the fossil biomarkers through the organic molecular composition of present-day biota.

Sediments from mountain lakes Trojrohé pleso (1,611 m a.s.l.; TROJ) and Batizovské pleso (1,884 m a.s.l.; BAT) and 12 ecological vegetation groups collected from the catchment of these lakes were processed using extraction and separation techniques (Bechtel et al. 2018, Freimuth et al. 2017) and analyzed for molecular and compound-specific isotopic composition by GC/MS and GC/IRMS.

Four chemostratigraphic units were defined in the lake TROJ (10,400 – 3,100 cal. yr BP) and five units in the lake BAT (16,200 – 4,400 cal. yr BP) with boundaries partly corresponding to climatic periods of Holocene.

In the Boreal, the earliest stage of TROJ lake, *Sphagnum* moss dominated and a combination of dwarf pine (*Pinus mugo)*, grasses, and geophytic lichens was present in minor proportions. *Sphagnum* retreated at the transition from the Boreal to Atlantic period, but reappeared episodically at 7,600 cal. yr BP. The Atlantic and Subboreal periods were dominated by dwarf pine scrubs with patches of meadows. A sharp increase in the retene concentration of the TROJ sediment in the period of 5,000 cal. yr BP was related to rise in the lake level due to fluctuation of hydrological conditions. According to n-alkane distribution, the present-day *Sphagnum* peat bog developed after 3,100 cal. yr BP.

The vicinity of BAT had a typical proglacial/paraglacial character in the late Pleistocene. Appearance at ca. 13,500 cal. yr BP and subsequent increase of diploptene concentration suggest a formation and gradual expansion of soil covered by grass and shrub vegetation and geophytic lichens. Thus the soil formation was synchronous with deglaciation of the valley ~13,300 cal. yr BP.

In the zone 13,500 – 11,500 cal. yr BP corresponding to the Older Dryas till Younger Dryas periods, *Sphagnum* moss retreated from BAT as a consequence of dry climate. The Preboreal and Boreal period seems to represent the most humid period with a massive expansion of *Sphagnum*. The return of alpine meadow habitats with the domination of ground shrubs and grasses appears in the Atlantic period. Lithophytic lichen biomarkers as one of the first colonizers of rock surface after deglaciation appeared in sediments due to extremely slow growth (Armstrong and Bradwell 2010) only in the middle Atlantic period.

While the sediments of TROJ preserved abietane since Boreal, an absence of this conifer biomarker in BAT sedimentary record signalizes that the upper limit of conifers, in this case dwarf pine, never reached the altitude above 1,900 m a.s.l.

Acknowledgement: This work was financially supported by the projects APVV-15-0292, APVV-20-0358, and VEGA2/0163/21.

References:

Armstrong, R. & Bradwell, T. 2010. Growth of crustose lichens: a review. *Geografiska Annaler Series A Physical Geography*, 92, 3–17.

Bechtel, A., Oberauer, K., Kostić, A., Gratzer, R., Milisavljević, V., Aleksić, N., Stojanović, K., Groß, D. & Sachsenhofer, R.F. 2018. Depositional environment and hydrocarbon source potential of the Lower Miocene oil shale deposit in the Aleksinac Basin (Serbia). *Organic Geochemistry*, 115, 93–112.

Fornace, K. L., Hughen, K.A., Shanahan, T.M., Fritz, S.C., Baker, P.A. & Sylva, S.P. 2014. A 60,000-year record of hydrologic variability in the Central Andes from the hydrogen isotopic composition of leaf waxes in Lake Titicaca sediments. *Earth and Planetary Science Letters*, 408, 263–271.

Račiška pečina sedimentary sequence: 3.4 Ma long record in cave sediments

NADJA ZUPAN HAJNA[1], PAVEL BOSÁK[2], PETR PRUNER[2], HELENA HERCMAN[3], IVAN HORÁČEK[4], JAN WAGNER[5], STANISLAV ČERMÁK[2], JACEK PAWLAK[3], PAULA SIERPIEŃ[3], ŠIMON KDÝR[2], LUCIE JUŘIČKOVÁ[4], ASTRID ŠVARA[1] and ANDREJ MIHEVC[1]

1 – Karst Research Institute ZRC SAZU, Titov trg 2, 6230 Postojna, Slovenia; e-mail: nadja.zupan-hajna@zrc-sazu.si

2 – Institute of Geology, the Czech Academy of Sciences, Rozvojová 269, 165 00 Praha 6, Czech Republic

3 – Institute of Geological Sciences, Polish Academy of Sciences, ul. Twarda 55/58, 00-818 Warszawa, Poland

4 – Department of Zoology, Faculty of Sciences, Charles University, Viničná 4, 128 45 Praha 2, Czech Republic

5 – Department of Paleontology, National Museum, Václavské náměstí 68, 110 00 Praha 1, Czech Republic

The sedimentary sequence in the Račiška pečina Cave (SW Classical Karst, Slovenia) deposited after long hiatus when the cave was detached from its hydrological function. The speleothem deposition was interrupted by numerous hiatuses and sedimentation of clay- to silt-sized material transported from the surface above the cave. The studied section in main passage is about 13 m long and 3 m high at the mouth of a narrow side passage. The composite sampled thickness was 6.34 m. The section is vertically composed of three principal segments: (1) the lower part: brown to reddish-brown massive but porous speleothems, with some interbeds of red clays, two principal angular unconformities, and the remains of broken stalagmites; (2) the middle part: sub-horizontal laminated, mostly porous flowstones intercalated by calcite rimstones and thick layers of red clay with rare fauna remains, very poorly preserved, fragile, and composed primarily of small fragments of tooth enamel (Horáček et al. 2007), and (3) massive, mostly laminated flowstones with two lens-like interbeds of yellow grey clay with large bone fragments. Some of the top flowstone layers contain black laminae enriched in organic carbon, which can be attributed to repeating Paleolithic and Neolithic human settlements in the cave (Zupan Hajna et al. 2021).

The high-resolution magnetostratigraphic profile was correlated with the GPTS (Cohen and Gibbard 2019) and calibrated by paleontological data (Horáček et al. 2007) and U-series plus radiocarbon numerical dates (Zupan Hajna et al. 2021). The lower part, according to fauna determined in the middle part above, was dated from ~3.4 Ma at the bottom up to 2.595 Ma at its top. In the middle part, the boundary of N- and R-polarized magnetozone within the basal layer with fauna can be identified with the bottom of C2n Olduvai subchron (1.925 Ma). The sequence represents the whole Olduvai subchron and terminates at 1.78 Ma. The upper part of the section starts shortly below Brunhes/Matuyama boundary (in R-polarized magnetozone) and terminates above youngest charcoal lamina (14C = ~3 ka). All thicker clay layers of the section were examined for faunal remains (Horáček et al. 2007) and helped to correlate the magnetostratigraphic profile with the GPTS and to interpret the cave environment (Moldovan et al. 2011; Zupan Hajna et al. 2021). Bones of large mammals in clays from upper part of profile allow the assignment to large cave bears (*Ursus* ex gr. *spelaeus*). Small mammal bones obtained from the upper part of the section belong to *Clethrionomys glareolus* or a form closely related to that extant species of late Early Pleistocene (Q2) to Recent. Another fragment can be tentatively attributed to the genus *Pliomys*, in which major radiation appeared during the earliest Pleistocene (MN17–Q1). Gastropods, their fragments, and imprints were found in red silty clays. They belong to endemic subterranean gastropod genus *Zospeum* sp., known mostly from Dinaric karst areas (Bole 1974) and they are the first found fossil subterranean snails. Three dark layers (soot) inside flowstone layers were dated by radiocarbon method to ~11 ka, ~9 ka, and ~3 ka (Zupan Hajna et al. 2021).

A detailed chronology of the Račiška pečina section based on magnetostratigraphy and isotopic oxygen stratigraphy was created based on paleontological, U-series, and radiocarbon benchmarks. The climatic changes during the growth of the section were up to ~2.6 – 2.5 Ma ago mostly controlled by global Atlantic Ocean factors, while by regional Mediterranean Sea factors above this datum. The sequence records geochronological and environmental data from the period of the last 3.4 Ma, including the Pliocene/Quaternary transition and both boundaries of the Olduvai Subchron. Matuyama/Brunhes transition zone is marked by dramatic changes of stable isotopic compositions, trace element concentrations and flowstone fabrics that point to temperature and precipitation changes (Zupan Hajna et al. 2021).

Acknowledgement: RVO6798531 (CZ), P6-0119 (SLO), OIS (PL).

References:

Bole, J. 1974. Die Gattung Zospeum Bourguignat 1856 (Gastropoda, Ellobiidae) in Jugoslawien. *Razprave Slovenske Akademije Znanosti in Umetnosti*, 17, 249–282.

Cohen, K. & Gibbard, P. 2019. Global chronostratigraphical correlation table for the last 2.7 million years QI 500. *Quaternary International,* 500, 20–31.

Horáček, I., Mihevc, A., Zupan Hajna, N., Pruner, P. & Bosák, P. 2007. Fossil vertebrates and paleomagnetism update one of the earlier stages of cave evolution in the Classical Karst, Slovenia: Pliocene of Črnotiče II site and Račiška pečina. *Acta Carsologica*, 37, 3, 451–466.

Moldovan, O., Mihevc, A., Mikó, L., Constantin, S., Meleg, I., Petculescu, A. & Bosák, P. 2011. Invertebrate fossils from cave sediments: a new proxy for pre-Quaternary paleoenvironments. *Biogeosciences,* 8, 7, 1825–1837.

Zupan Hajna, N., Mihevc, A., Bosák, P., Pruner, P., Hercman, H., Horáček, I., Wagner, J., Čermák, S., Pawlak, J., Sierpień, P., Kdýr, Š, Juřičková, L. and Švara, A. 2021. Pliocene to Holocene chronostratigraphy and paleoenvironmental records from cave sediments: Račiška pečina section (SW Slovenia). *Quaternary International,* 605–606, 5–24.

doc. Mgr. Natália Hudáčková, PhD.
Mgr. Andrej Ruman, PhD.
doc. RNDr. Michal Šujan, PhD.

Editors

Environmental, Structural and Stratigraphical Evolution of the Western Carpathians

Abstract Book

Published by the Comenius University Bratislava, 2022
Graphic design: doc. RNDr. Michal Šujan, PhD.
Cover graphics: Collage of figures published in open access journals
by the following authors (in alphabetical order):
Marija Bošnjak, Tamás Csibri, Jerzy Dec, László Fodor, Jan Golonka,
Mathias Harzhauser, Natália Hudáčková, Peter Joniak, Michal Kováč,
Elżbieta Machaniec, Imre Magyar, Oleg Mandic, Marína Molčan Matejová,
Franz Neubauer, Daniel Pivko, Tomáš Potočný, Luca Reato, Ján Schlögl,
Krisztina Sebe, Ján Soták, Jasenka Sremac, Michal Šujan

164 pages, first edition, 115 copies,
released as an electronic publication

ISBN: 978-80-223-5518-6 (printed version)
ISBN: 978-80-223-5519-3 (online version)

ISBN 978-80-223-5519-3