6. HRVATSKI GEOLOŠKI KONGRES
s međunarodnim sudjelovanjem

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09.–12. 10. 2019.
Zagreb

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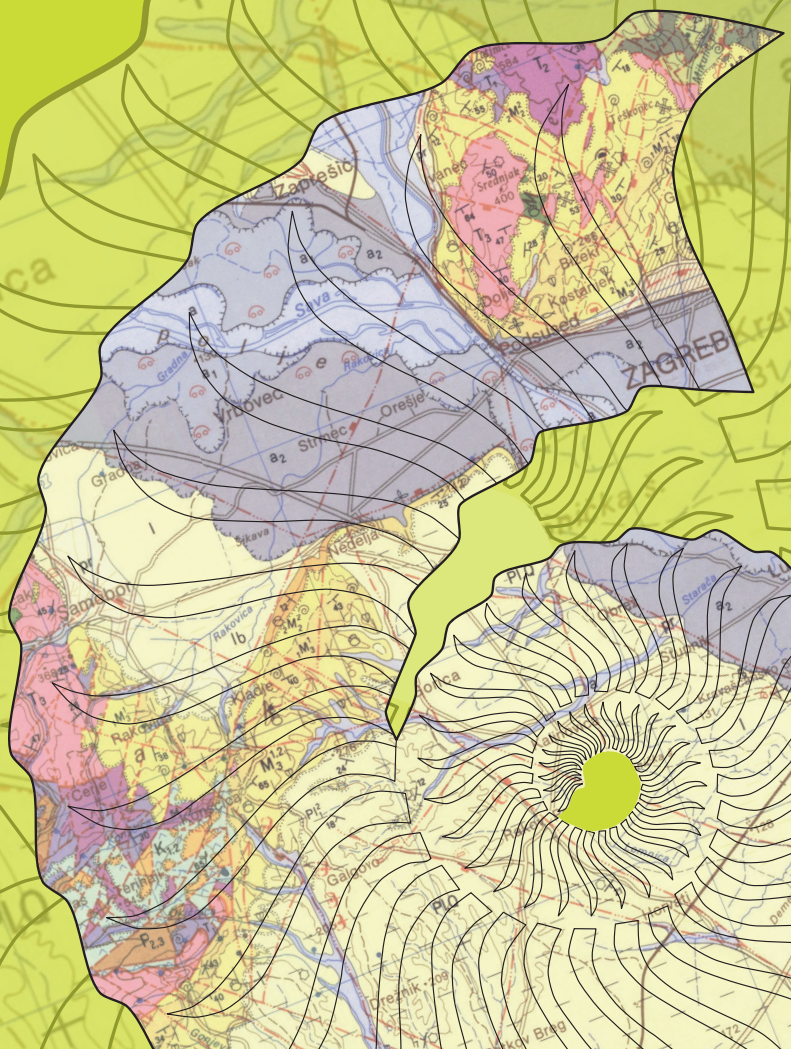

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Marija HORVAT • Bojan MATOŠ • Lara WACHA

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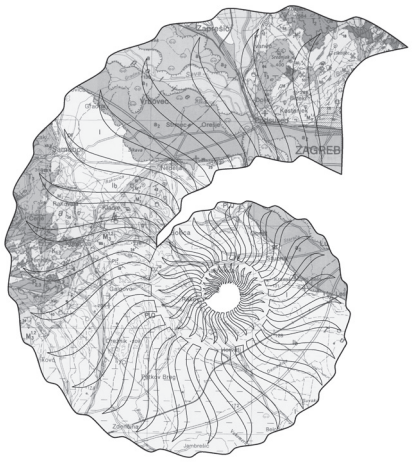
KNJIGA SAŽETAKA
ABSTRACTS BOOK



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INVITED LECTURER

Geology in Croatia – Situation and Perspective

Mladen Juračić[1*]

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The organization of geological research and work in Croatia, both in academy and in industry, has significantly changed in the last five years. The focus of scientific research, the way of its financing, and the organization and structure of geological institutions and companies significantly changed. Research for oil and gas is substantially reduced, and geological research related to the large civil engineering constructions is also diminishing, whereas the funding of small and short-term scientific projects, however as interesting and important they might be, caused the inability to fund extensive and systematic geological research. A positive exception is a significant increase in the research of Recent and Quaternary geological sediments and processes. In such a situation, even after repeated attempts, unfortunately, we do still not have the Law on geological research and geological activities.

Geologists' education and training should take into account the observed changes, and the enrolment quotas and programs of basic and applied geology study programs should be adapted to the existing situation, however with major effort to improve the current state.

Keywords: *research, organisation, financing, law, education*

INVITED LECTURER

Reconstructing Submerged Landscapes Using Marine Geophysical Data: Case Studies From Mediterranean Sea

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It is worldwide approved that the marine geophysical techniques constitute a powerful approach in the underwater archaeology. The last two decades, the successful application of the remote sensing techniques to underwater archaeological sites has provided the base of a new scientific discipline "Marine Geoarchaeology". There are two general methodological approaches in Marine Geoarchaeology; the remote sensing techniques are being increasingly used to identify, locate and map: (i) the coastal palaeogeography and thus submerged sites of archaeological interest (submerged ancient cities, settlements, harbours and man-made structures), and (ii) ancient and historical shipwrecks lying on the seafloor or buried beneath sediments. More specifically, marine geophysical techniques have been widely used in studies focusing on the reconstruction of coastal palaeogeography at submerged sites of archaeological interest mainly by detecting and mapping the preserved palaeoshorelines and by studying the local stratigraphy and Late Quaternary geology. Furthermore, they have been widely used in underwater archaeological studies regarding the detection and investigation of archaeological sites such as ancient shipwrecks and the related site formation processes due to the ability to investigate and map the seabed and subsurface features at high speeds and independently of the water depth and the visibility.

In this paper, the results of marine geoarchaeological surveys, which have been carried out in important archaeological sites of Greece, will be briefly presented. The surveys have been conducted with the co-operation of Ephorate of Underwater Archaeology and the University of Copenhagen/Danish Institute at Athens (Zea Harbour project), the Finnish Institute at Athens (Kyllene Harbour Project), the University of Tennessee (Mitrou Archaeological Pro-

ject) and with the Hellenic Institute of Marine Archaeology (Modi area) and the University of Athens (Neapoli Gulf). Moreover a series of surveys will be also presented, undertaken by our Laboratory in Alexandria (CEAlex), Croatia (Univ. Zadar, Hrvatski Geološki Institut), Corsica (DRASSM), Lebanon (HFF, CNRS-L) and in Cyprus (Mazotos shipwreck, Univ. of Cyprus).

Keywords: *submerged landscapes, geophysical techniques, marine geoarcheology, Greece*

INVITED LECTURER

Biostratigraphy and Depositional Environments of the Early and Middle Triassic Deposits in the Dinarides: State of the Art

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The Early and Middle Triassic deposits that extend along the Dinarides were investigated in the frame of western Tethyan evolution by many authors (BABIĆ, 1968; GRIMANI et al., 1975; SOKAČ et al., 1976; HERAK et al., 1983; ŠĆAVNIČAR & ŠUŠNJARA, 1983; ŠĆAVNIČAR et al., 1984; TIŠLJAR, 1992; JELASKA et al., 2003; KOLAR-JURKOVŠEK et al., 2011; KOLAR-JURKOVŠEK & JURKOVŠEK, 2015; 2019 and many others).

The Early Triassic rocks were traditionally devided into two lithologically different units following the historic division of the Werfen Formation: the dominantly clastic red coloured Seis beds ("*Seiser Schichten*") and dominantly carbonatic, grey, Campiler beds ("*Campiler Schichten*"). A lithostratigraphic meaning was soon assigned to these two units. Seis beds have been usually considered as lower part of the Early Triassic or Induan, while Campiler beds were considered as late Early Triassic or Olenekian.

Recent investigations of the Early Triassic rocks (in the External Dinarides of Slovenia, Croatia and Bosnia and Herzegovina) intent to provide more exact litho-, bio-, and chemostratigraphic constraints of the Early Triassic strata (Seis and Campil beds) that enable to establish the Early Triassic stage and sub-stage boundaries. The investigations began as a detailed definition of the Permian-Triassic boundary (PTB) with a significant contribution by KOLAR-JURKOVŠEK et al. 2011; 2018; FIO et al., 2010). Detailed research of the Early Triassic depositional sequences was performed by analysing the facies and depositional environments accompanied by analysis of biochronologically significant conodont associations and chemostratigraphic data based on the ^{13}C-isotope curve. It was found that in the western Tethys shallow water limestones, dolostones and evaporites were deposited at the end of Permian. During the Early Triassic, a depositional environment developed as a shallow Tethyan bay that mostly resembles a vast epicontinental sea. A trend of long-term global sea-level rise shifted the coastline toward the W-NW until the Spathian. Lithology at the most studied sections reveal a general three-fold division: the oldest strata consist of carbonates, the middle strata are siliciclastic or mixed carbonate-siliciclastic, and the youngest strata are carbonatic. The oldest Griesbachian carbonates, mostly dolostone, conformably overly Upper Permian deposits. Their stratigraphic position was documented by the *Hindeodus-Isarcicella* conodont population in Slovenia (localities Lukač and Masore, KOLAR-JURKOVŠEK et al., 2011; 2018) and in Croatia (localites in the Gorski Kotar, on Velebit Mts. and near Knin). In the uppermost Griesbachian the increase of siliciclastic component occurred and a sandstone-siltstone-shale intercalation with minor occurrences of ooid grainstones (former Seis beds) were deposited throughout the whole Dienerian and lasted to the end of Smithian. Dienerian age was proven by presence of conodont genus *Hadrodontina* and bivalve *Claraia clarai* (Emmr.). The siliciclastic deposition in the Smithian was documented by abundant occurrence of *Pachycladina obliqua* (STAESCHE, 1964). The deposition of this specific lithologic unit extends from the late Induan to the early Olenekian (Dienerian to Smithian), thus suggesting that the previously applied lithostratigraphic division should be revised. The drastic change in the depositional style with the prevalence of carbonates (lime mudstones and marls, former Campil beds) occurred in the Spathian (proven by findings of conodont genus *Triassospathodus*). Division to sub-stage boundaries established by conodont zonation was correlated with the ^{13}C-isotope curve from the continuous section near Knin (ALJINOVIĆ et al., 2018). The curve shows a significant increase from the negative values in the Griesbachian to a prominent maximum around the Dienerian-Smithian boundary, followed by a continuous decline to negative values in the Smithian. Around the Smithi-

an-Spathian boundary a steep rise to a second maximum occurred.

Considering the paleogeographic position of the External Dinarides in the shallow sea of the western Tethyan edge as well as the facies characteristics the depositional environment was envisaged as an epicontinental ramp (a large shallow area with the characteristics of carbonate platform and carbonate ramp). It should be emphasized that the deposition was influenced by storms and occurred under the transgressive conditions.

After the tectonically stabile period in the Early Triassic, the epeiric ramp disintegrated by severe wrench and block tectonic where some blocks were uplifted and subaerially exposed, some remained shallow marine, dominated by carbonates (GRGASOVIĆ & SOKAČ, 2003), while others subsided and developed as pelagic or deeper marine realms. The tectonic movements were accompanied by the volcanic activity that produced various types of volcanic and volcaniclastic rocks. Volcanics are presented by occurrences of basaltic and andesitic bodies. Volcaniclastic deposits are represented by crystaloclastic and vitriclastic tuffs of andesitic to rhyolitic composition, peperites formed by mixing of magma and unconsolidated water saturated sediments, hyaloclastics, ignimbrites (SMIRČIĆ, 2017) and gravity flow resedimented pyroclastic rocks (BELAK, 2000; MARJANAC, 2000). Volcaniclastics investigated in Lika, Velebit Mts, and Zelovo (Croatia), and Bosansko Grahovo (Bosnia and Herzegovina) are in contact with different types of sedimentary rocks. The age of volcanism was concluded by means of conodonts and ammonoids from the associated limestones indicating that volcanic activity started already in the Anisian (lower Illyrian) and lasted till Longobardian (Ladinian) (SMIRČIĆ, 2017) similar as in the surrounding Western Tethyan territories.

Keywords: *Early Triassic, Middle Triassic, western Tethys, epeiric ramp, volcaniclastics, biostratigraphy, chemostratigraphy*

References

ALJINOVIĆ, D., HORACEK, M., KRYSTYN, L., RICHOZ, S., KOLAR-JURKOVŠEK, T., SMIRČIĆ, D. & JURKOVŠEK, B. (2018): Western Tethyan epeiric ramp setting in the Early Triassic: An example from the Central Dinarides (Croatia). Journal of Earth Sciences, 29, 4, 806-823.

BABIĆ, Lj. (1968): O trijasu Gorskog kotara i susjednih područja. (Sur le Trias dans le Gorski Kotar et les regions voisines). Geol. vjesnik, 22, 11-23.

BELAK, M. (2000): Postaja 2: profil Sutina-Zelovo Sutinsko; Kristaloklastični i vitoroklastični tufovi (pietra verde) s proslojcima silicificiranih dolomita, vapnenaca, tufita i rožnjaka. U: JELASKA, V., BENČEK, Đ., MATIČEC, D., BELAK, M. & GUŠIĆ, I: Geološka povijest i strukturna evolucija Vanjskih Dinarida. - Vodič ekskurzija (VLAHOVIĆ, I. & BIONDIĆ, R. Eds.). 2. Croatian geological congress, Cavtat-Dubrovnik, 6-9, IGI, Zagreb.

FIO, K., SPANGENBERG, J.E., VLAHOVIĆ, I., SREMAC, J., VELIĆ, I. & MRINJEK, E. (2010): Stable isotope and trace element stratigraphy across the Permian-Triassic transition: a redefinition of the boundary in the Velebit Mountain, Croatia. Chemical geology, 278, 38-57.

GRGASOVIĆ, T. & SOKAČ, B. (2003): Review on fossil dasycladacean associations in the Triassic of Croatia. Acta Micropalaeontologica Sinica, 20, 75-79.

GRIMANI, I., ŠIKIĆ, K. & ŠIMUNIĆ, An. (1975): Osnovna geološka karta SFRJ, 1:100 000, Tumač za list Knin (Basic geologic map SFRJ Explanatory notes to geological map – Knin; Abs: Geology of the Knin sheet). Institut za geološka istraživanja Zagreb, Savezni geol. zavod Beograd, 61 p.

HERAK, M., ŠĆAVNIČAR, B., ŠUŠNJARA, A., ĐURĐANOVIĆ, Ž., KRYSTYN, L. & GRUBER, B. (1983): Neue Beiträge zur Biostratigraphie der Tethys-Trias. Lower Triassic of Mućd. Proposal for standard section of the European Upper Scythian. Schr. Erdwiss., 5, 93-106.

JELASKA, V., KOLAR-JURKOVŠEK, T., JURKOVŠEK, B. & GUŠIĆ, I. (2003): Triassic beds in the basement of Adriatic-Dinaric carbonate platform of Mt. Svilaja (Croatia), Geologija. 46, 225-230, Ljubljana.

KOLAR-JURKOVŠEK, T. & JURKOVŠEK, B. (2015): Conodont zonation of Lower Triassic strata in Slovenia. Geologija, 58, 155-174.

KOLAR-JURKOVŠEK, T. & JURKOVŠEK, B. (2019): Konodonti Slovenije / Conodonts of Slovenia. Geološki zavod Slovenije, Ljubljana, 260 p.

KOLAR-JURKOVŠEK, T., JURKOVŠEK, B. & ALJINOVIĆ, D. (2011): Conodont biostratigraphy and lithostratigraphy across the Permian-Triassic boundary at Lukač section in western Slovenia. Rivista Italiana di Paleontologia e Stratigrafia, 117, 115-133.

KOLAR-JURKOVŠEK, T., JURKOVŠEK, B., NESTELL, G. & ALJINOVIĆ, D. (2018): Biostratigraphy and sedimentology of Upper Permian and Lower Triassic strata at Masore, Western Slovenia. Palaeogeography, Palaeoclimatology, Palaeoecology, 490, 38-54.

MARJANAC, T. (2000): Triassic of Dalmatia – Evidence of a failed rift (Muć section). PANCARDI 2000, Vijesti Hrv. geol. dr., 37/2, 117-126.

SMIRČIĆ, D. (2017): Genesis of Middle Triassic volcaniclastic deposits in the External Dinarides. Unpubl. PhD Thesis, Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, 217 p.

ŠĆAVNIČAR, B. & ŠUŠNJARA, A. (1983): The geologic column of the Lower Triassic at Muć (Southern Croatia). Acta Geologica, 13, 1-25, Zagreb.

ŠĆAVNIČAR, B., ŠĆAVNIČAR, S. & ŠUŠNJARA, A. (1984): The volcanic-sedimentary Middle Triassic in the Suvaja brook area (Mt. Svilaja, Outer Dinarides). Acta Geologica, 14/2, 35-82.

SOKAČ, B., ŠĆAVNIČAR, B. & VELIĆ, I. (1976): Osnovna geološka karta SFRJ 1:100 000. Tumač za list Gospić L 33-127. Institut za geološka istraživanja Zagreb, Savezni geološki zavod Beograd, 64 p.

TIŠLJAR, J. (1992) Origin and depositional environments of the cvaporite and carbonate complex (Upper Permian) from the central part of the Dinarides (Southern Croatia and Western Bosnia). Geol. Croatica, 45, 115-127.

INVITED LECTURER

The Development of the Neogene North Croatian Basin: From the Land to the Sea and Back

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The Neogene North Croatian Basin (NCB) is situated in the southwestern part of the Pannonian Basin System (PBS), and except for its northwesternmost segment, geographically covers the entire area of Pannonian Croatia. It is a rift type basin whose formation was controlled by tectonics, changes in climate, volcanic activity and eustatic fluctuations. The accumulated sedimentary succession thickness in places reaches up to 7 km (SAFTIĆ et al., 2003). These sediments were initially deposited in alluvial and lacustrine environments, followed by marine environments, and then a return to lacustrine and alluvial, thus displaying a major transgressive-regressive sedimentary cycle (PAVELIĆ & KOVAČIĆ, 2018). The time span of the basin formation and duration of the individual phases in its development were, until recently, chiefly defined based on mainly fossil communities and superposition. However, temporary endemism caused stratigraphic problems within the NCB and correlation with neighboring areas. The problems were not resolved until using multidisciplinary investigations which were carried out during the last ten years. Combined radiometric dating of tuff layers and integrated bio-magnetostratigraphy improved the time span for the formation and development of the NCB.

Deposition within the NCB commenced in the Early Miocene within terrestrial sedimentary environments which were under strong influence of cyclic shifts between arid and humid climate conditions. Alluvial sediments were deposited over an unconformity above basement rocks of the NCB, and are in places interlayered with pyroclastics and loess deposits, while sediments deposited in a salina type lake have also been documented (KOVAČIĆ & PAVELIĆ, 2017). Radiometric dating of tuff interlayers from the lower part of the alluvial sequence (MANDIC et al., 2012), as well as tuffs from the overlying lacustrine deposits (MARKOVIĆ, 2017), has confirmed the previously supposed Ottnangian age of the oldest Miocene sediments in the NCB. Also, it has been newly determined that the deposition of alluvial and salina lake sediments continued into the Karpatian. Terrestrial depositional environments persisted in the NCB into the early Badenian within lacustrine environments where mainly clastic pelitic sediments with tuff layers were deposited. Their fossil assemblage indicates deposition within interchanging freshwater and brackish lacustrine conditions without any connection with the sea (MANDIC et al., 2018). Radiometric dating on tuff layers indicates that lacustrine environments persisted in the NCB area up to approximately 15 Ma (MARKOVIĆ, 2017). As a consequence, the beginning of the marine transgression, previously assigned to the Ottnangian/Karpatian boundary based on superposition, has been shifted to the beginning of the middle Badenian.

The marine phase of the NCB covers the middle to late Badenian and Sarmatian time period, during which the area represented the southwestern marginal segment of the Central Paratethys (CP) (PAVELIĆ & KOVAČIĆ, 2018). During the middle and late Badenian diverse pelitic, carbonate and carbonate-clastic sediments with pyroclastic interlayers were deposited continuously onto lacustrine deposits or above an unconformity, covering various basement rocks. Radiometric dating of tuffs (MARKOVIĆ, 2017) confirmed their stratigraphic age which had previously been defined based on the rich fossil community present in the marine sediments. Following the late Badenian transgression, which marks the peak of the transgressive cycle in the NCB, a general regressive sedimentary succession begins. Within it, different Sarmatian clastic and carbonate sediments were deposited over the upper Badenian carbonate sediments in conditions of reduced volcanic activity and weakening connections between the CP and surrounding marine realms. Gradual isolation of the CP and a reduction in water salinity led to an extinction of stenohaline marine organisms at the Badenian/Sarmatian boundary, and allowed the development of a new community adapted to the life in a marine environment of reduced salinity.

The continuing trend of CP's isolation led to a complete isolation of the PBS from surrounding marine realms, the termination of marine sedimentation and the formation of the brackish Lake Pannon. In the newly formed lake, a stratigraphically ambiguous endemic community of organisms developed. This circumstance, together with a lack of pyroclastics, has caused problems in the subdivision of the thick succession of Upper Miocene lacustrine deposits in the NCB area, and their correlation with neighboring regions. It has been shown that the fossil communities of mollusks based on which they are divided into *Croatica*, *Banatica*, *Abichi* and *Rhomboidea* layers, depended on depositional facies and are diachronous, as well as that the Pontian stage is incorrectly applied in the PBS area (PILLER et al., 2007). The deposition of the Upper Miocene lacustrine sediments

in the NCB is characterized by a transgressive-regressive cycle. In the older, transgressive part of the cycle, limestones predominate. These are overlain by marly sediments with rare interlayers of sand and gravel while the younger, regressive part of the cycle, is characterized by deposition of sandy-silty clastic detritus supplied into the lake by deltaic systems (PAVELIĆ & KOVAČIĆ, 2018). These systems prograded into the area of the NCB from the north and the northwest that generated gradual shallowing of the lake and final infilling (KOVAČIĆ et al., 2004). Notably, before the end of the Miocene the north and northwest part of the NCB were transformed into an alluvial plain. In the southeastern part of the basin the Lake Pannon persisted into the early Pliocene, when it was replaced by the freshwater Lake Slavonia. Within it, from the middle Pliocene to the early Pleistocene, a variety of clastic sediments were deposited, previously known as *Viviparus* beds, which have been found to represent a new independent phase of the development of the basin, and have accordingly been defined as the newly proposed regional Cernikian stage (MANDIC et al., 2015). Since the early Pleistocene, the entire area of the NCB is once again represented by terrestrial sedimentary environments.

Keywords: *North Croatian Basin, Neogene, transgressive-regressive cycle*

References

KOVAČIĆ, M., ZUPANIČ, J., BABIĆ, LJ., VRSALJKO, D., MIKNIĆ, M., BAKRAČ, K., 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.

KOVAČIĆ, M. & PAVELIĆ, D. (2017): Neogene stratigraphy of the Slavonian Mountains. In: KOVAČIĆ, M., WACHA, L. & HORVAT, M. (eds.): The 7th International Workshop on the Neogene from the Central and South-Eastern Europe. 28–31 May, 2017, Velika, Croatia. Field trip guidebook. Croatian Geological Society, Velika, 5-9.

MANDIC, O., De LEEUW, A., BULIĆ, J., KUIPER, K.F., KRIJGSMAN, W. & JURIŠIĆ-POLŠAK, Z. (2012): Paleogeographic evolution of the southern Pannonian Basin: 40Ar/39Ar age constraints on the Miocene continental series of northern Croatia. Int. J. Earth Sci., 101, 1033-1046.

MANDIC, O., KUREČIĆ, T., NEUBAUER, T.A. & HARZHAUSER, M. (2015): Stratigraphic and palaeogeographic significance of lacustrine molluscs from the Pliocene Viviparus beds in Central Croatia. Geol. Croat., 68, 179-207.

MANDIC, O., HAJEK-TADESSE, V., BAKRAČ, K., REICHENBACHER, B., GRIZELJ, A. & MIKNIĆ, M. (2018): Multiproxy reconstruction of the middle Miocene Požega palaeolake in the Southern Pannonian 2 Basin (NE Croatia) prior to the Badenian transgression of the Central Paratethys Sea. Palaeogeography, Palaeoclimatology, Palaeoecology, 516, 203-219.

MARKOVIĆ, F. (2017) Miocenski tufovi Sjevernohrvatskoga bazena (Miocene tuffs from North Croatian Basin – in Croatian, with an English Abstract). Unpubl. PhD Thesis, Faculty of Science, University of Zagreb, 174 p.

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.

PILLER, W.E., HARZHAUSER, M. & MANDIĆ, O (2007): Miocene Central Paratethys stratigraphy – current status and future directions. Stratigraphy, 4, 154-168.

SAFTIĆ, B., VELIĆ, J., SZTANÓ, O., JUHÁSZ, G. & IVKOVIĆ, Ž. (2003): Tertiary subsurface facies, source rocks and hydrocarbon reservoires in the SW part of the Pannonian Basin (northern Croatia and south-western Hungary). Geol. Croat., 56, 101-122.

INVITED LECTURER

Use of Geochemical Methods in the Research of Groundwater Systems

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The chemical composition of groundwater is controlled by dissolution and by chemical reactions with solids, liquids and gases with which they come into contact during the various phases of the hydrological cycle (STUMM & MORGAN, 1995). Over the past 50 years, the geochemical parameters such as basic chemical composition, REE (rear earth elements), stable (deuterium, oxygen-18 & -17, carbon-13, nitrogen-15 etc) and radioactive isotopes (carbon-14, tritium, radon-222, uranium-238, chloride-36 etc) gases (methane, carbon dioxide, etc) and noble gases (helium, argon, krypton, neon) and geochemical modelling, are often used to investigate groundwater origin, residence time and to improve understanding of how structural, geological, mineralogical, and hydrological features affect flow and chemistry in the groundwater system.

The variation of the chemical composition of groundwater along a flow path is influenced by the spatial variation of minerals and rocks, the initial composition of the recharge solution and geochemical reactions such as oxidation-reduction reactions, sorption and exchange reactions and transformation of organic matter etc. Geochemical modelling is used for quantifying the geochemical reactions occurring along the flow paths within groundwater systems using geochemical software such as NETPATH, PHREEQC, GWB etc.

The application of above mentioned geochemical parameters as a tool in the hydrogeological investigation of thermal and "cold" groundwaters will be demonstrated at the few examples from Croatia, to show how can be geochemical methods in combination with other methods useful in determination of groundwater origin, residence time and hydrological features affect flow.

Although the use of geochemical parameters is not perfect and some improvements are needed in the interpretation of the obtained information, and in the construction and interpretation of numerical models using geochemical data, the best approach will ensure an optimized iterative process between field data collection and analysis, interpretation, and the application of forward, inverse, and statistical modelling tools.

Keywords: *geochemical parameters, isotopes, geochemical modelling, groundwater*

References

STUMM,W, & MORGAN, J.J. (1996): Aquatic chemistry. Chemical Equlibria and Rates in Natural Waters. New York – Chichester – Brisbane – Toronto – Singapore: John Wiley & Sons, 348 p.

INVITED LECTURER

Hydrocarbon Source Rock of the Dinarides: an Overview and Future Challenges

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The Dinarides are a complex folded, faulted and imbricate belt along the NE margin of the Adriatic Sea. This mountain chain consists of a thick rock succession ranging from Carboniferous to Quaternary. The coastal zone and islands are mainly composed of carbonates that belong to the several palaeogeographic entities (VLAHOVIĆ et al., 2005). The widespread organic matter occurrences throughout area has attracted attention and encouraged petroleum exploration since 1970s.

During years, a comprehensive geochemical evaluation is performed on more than 5000 outcrops and boreholes samples. Based on this huge data set, potential source rocks are verified in several stratigraphic levels. More importantly, source rock-hydrocarbons genetic correlations and petroleum system evaluations are established, as well. In the Northern Adriatic offshore biogenic gas accumulations of Plio-Pleistocene system are under production. The aim of this overview is to represent source rock potential of the rest of the area.

Organic-rich siliciclastics and carbonates of the Carboniferous and Permian age are source rock with no potential due to metagenetic or metamorphous stage of thermal transformation. Organic-rich sediments of Triasssic and Early Jurassic age generally have poor source rock characteristics. They are in the higher catagenesis with transition to metagenesis. Regular appearances of pyrobitumen in these rocks indicate hydrocarbon generation in the past.

On contrary, Upper Triassic organic-rich laminated limestones of Vlasta-Komiza facies are very good to excellent oil-prone source rocks that have reached onset of oil generation (COTA & BARIĆ, 1998). Organic matter is a mixture of algal, bacterially degraded kerogen and migrated bitumen. Kerogen is type II to II-S. Stable carbon isotopes and biomarkers confirmed origin and deposition in the low energy, highly anoxic, lagoonal, carbonate-evaporitic environment. However, only small oil volume was recovered. Oil is positively correlated with the Triassic source rock. An attempt has been made to map this source rock horizon in

relation to Burano formation (Italy) throughout the wider Adriatic area. Determined differences of Triassic successions have highlighted the necessity of detail sedimentary basin evolution of the extensional/rift basins, facies distribution and understanding of the pre-platform rift systems and their thermal subsidence history as a prerequisite to evaluate the survivability of syn- to post-rift petroleum systems. The lack of high-quality genetic model hampered the otherwise valiant attempts to chase the Mesozoic carbonate oil play in the Dinarides.

The best source rock of the Dinarides are Upper Jurassic dark organic-rich laminated limestones with cherts deposited in the older part of Lemeš trough (TROSKOT-ČORBIĆ, 2011). Organic facies is characterized with high organic matter content, excellent hydrocarbon potential and high transformation ratio. These very good to excellent oil-prone source rocks contain kerogen type II of marine, algal-bacterial origin. Amorphous organic matter gradually changes from lamalginite to bituminite. Solid bitumen is incorporated in all structural types. The organic facies generally has reached onset of oil generation. High percentages of organic-bonded sulphur confirm that organic matter formation took place in the marine, carbonate environment with contemporaneous sulphur incorporation into a kerogen macromolecule structure. This kind of organic facies enabled hydrocarbon generation at lower degree of thermal transformation. Consequently, the total bitumen yields are high. Bituminous coatings in nearby area show high degree of similarity indicating short migration pathways.

Cretaceous laminated organic rich carbonates, deposited in the restricted lagoons and intraplatform troughs, are also excellent source rock. Organic matter is of microbial and algal origin. Kerogen is type II to I. Organic matter is immature. Organic facies is typical oil prone and enriched in sulphur incorporated in kerogen structure enabling hydrocarbon generation at lower degree of thermal transformation. These Cretaceous oil prone source rocks are also distributed over the central Adriatic offshore area (COTA & BARIĆ, 1998). At depths of 4,500 to 5000 m sediments have reached oil window. According to stable carbon isotopes and biomarkers these low maturity Cretaceous source rocks are sourcing heavy hydrocarbons that are registered in non-commercial quantities in few Adriatic offshore wells or as oil shows (migrabitumens) that filled fissures, cavities and pores in widespread area.

The wider Mediterranean area hosts a significant number of petroleum provinces (ZAPPATERRA, 1994). Active source rocks, genetically related oil and gas and all the geologic elements and processes that are essential, if an oil and gas accumulation is to exist, are evidenced in the Dinarides, as well. Understanding the thermal history and the structural-tectonic relationships that influenced it are fundamental in future research.

Keywords: *source rock, generative potential, Dinarides*

References

COTA, L. & BARIĆ, G. (1998): Petroleum Potential of the Adriatic offshore, Croatia. Organic Geochemistry, 29, 1-3, 559-570.

TROSKOT-ČORBIĆ, T. (2011): Organski facijesi u gornjojurskim naslagama Gorskog kotara, Like i Dalmacije [Organic facies of the Upper Jurassic sediments in Gorski kotar, Lika and Dalmatia – in Croatian with an English Abstract]. Unpubl. PhD Thesis, Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, 266 p.

VLAHOVIĆ, I., TIŠLJAR, J., VELIĆ, I. & MATIČEC, D. (2005): Evolution of the Adriatic Carbonate Platform: Palaeography, main events and depositional dynamics. Palaeogeography, Palaeoclimatology, Palaeecology, 220, 333-360.

ZAPPATERRA, E. (1994): Source-Rock Distribution Model of the Periadriatic region. AAPG Bulletin, 78, 3, 333-354.

Petrophysical Evaluation on Cenozoic Formations and its Possible Potential to Accumulate Hydrocarbon in the Southern Part of Cesar Sub-Basin, Colombia

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Evidence of source rock maturity, hydrocarbon generation and expulsion in Cesar sub-basin (AYALA, 2009; MESA & RENGIFO, 2011; SÁNCHEZ & MANN, 2015) turn this site into an object of significant exploratory interest, where Mesozoic, Miocene and Pliocene units correlative with Maracaibo basin, a world-class hydrocarbon basin (LUGO & MANN, 1995; MANN et al., 2006), suggest the existence of an analogous petroleum system in Cesar sub- basin, being the Cenozoic clastic section the main reservoir target, although still unexplored with probability for high potential to accumulate conventional hydrocarbons or coal-bed methane (CBM) (GARCÍA et al., 2007; MESA & RENGIFO, 2011). Well logs interpretation techniques provide accurate and reliable information as a success tool in reservoir evaluation (RIDER & KENNEDY, 2011; WU & GRANA, 2017). Therefore, a petrophysical evaluation was carried out on Cenozoic sandy bodies to define the conventional or non- conventional hydrocarbon accumulation potential of the southern part of Cesar sub-basin.

A lithologic correlation of equivalent Cenozoic units across the study wells was done from core descriptions, stratigraphic information and electrical logs responses. Well logs analysis were used to evaluate the petrophysical parameters such as shale volume (Vsh), effective porosity (Øe), total porosity (Øt), water saturation (Sw) and true resistivity (Rt) of Cenozoic clastic rocks in the southern part of Cesar sub basin. Lithological compositions, shale volume, effective porosity, and water saturations were illustrated on templates and cross-plots, relations between permeability and porosity were used to clarify the petrophysical behavior in the rock types defined, relating the petrophysical parameters with the geologic setting of the study area.

Stratigraphic and petrophysical data and their relation with core information about Cenozoic clastic section of Cesar sub-basin reveal that the Medium member of Cuervos formation consists mainly of sandstones and shales with 27% shale volume on average, high values of effective porosity about 20% and water saturations determined by Simandoux equation (SIMANDOUX, 1963) below 30%, characteristics that turn this member in a promising reservoir especially in trends SW-NE. This study will contribute new data to state and support the feasibility of future exploration projects in the area.

Keywords: *well logs, petroleum system, petrophysical parameters, reservoir, Cesar sub-basin, Cenozoic section*

References

AYALA, R.C. (2009): Análisis tectonoestratigrafico y de procedencia en la subcuenca de Cesar: Relacion con los Sistemas Petroleros: Unpublished M.Sc. thesis, Facultad de Ciencias, Universidad Simon Bolivar, Caracas, Venezuela, 188 p.

GARCIA, M., MIER, R., ARIAS, A., CORTES, Y., MORENO, M., SALAZAR, O. & JIMENEZ, M. (2007): Prospectividad de la cuenca Cesar-Ranchería. Informe Agencia Nacional de Hidrocarburos, Colombia, 248 p.

LUGO, J. & MANN, P. (1995): Jurassic-Eocene tectonic evolution of Maracaibo Basin, Venezuela. In: TANKARD, A.J., SUAREZ, R. & WELSINK, H.J. (eds.): Petroleum basins of South America: AAPG Memoirs, 62, 699-725.

MANN, P., ESCALONA, A. & CASTILLO, M.V. (2006): Regional geologic and tectonic setting of the Maracaibo supergiant basin, western Venezuela: AAPG Bulletin, v. 90, 445-478.

MESA, A. & RENGIFO, S. (2011): Petroleum Geology of Colombia–Cesar Rancheria Basin Vol 6. Agencia Nacional de Hidrocarburos-ANH, 159 p.

RIDER, M.H. & KENNEDY, M. (2011): The geological interpretation of well logs. Rider-French Consulting Limited, 432p.

SANCHEZ, J. & MANN, P. (2015): Integrated Structural and Basinal Analysis of the Cesar–Rancheria Basin, Colombia: Implications for its Tectonic History and Petroleum Systems: 431-470.

SIMANDOUX, P. (1963): Dielectric measurements on porous media application to the measurement of water saturations: study of the behaviour of argillaceous formations: Revue de l'Institut Francais du Petrole 18, Supplementary Issue, 193-215.

WU, W. & GRANA, D. (2017): Integrated petrophysics and rock physics modelling for well log interpretation of elastic, electrical, and petrophysical properties. Journal of Applied Geophysics, 146, 54-66.

Sediment-Quality Information, Monitoring and Assessment System to Support Transnational Cooperation for Joint Danube Basin Water Management – SIMONA Project

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Over the past decades, human activities within the Danube River Basin (DRB) have led to strong changes in the sediment quality. Hazardous Substances (HSs) pollution can cause severe damage to the ecosystems and can have direct effects to the health of the human population. The Joint Danube Surveys (JDS 1 and 2) characterized HSs in the Danube sediment several years ago and they concluded that contaminated sediment with HSs is an existing problem in the Danube River Basin. Most of the DTP countries face serious challenges of the implementation of the HSs concentration monitoring in the surface water sediments as required by the EU Water Framework Directive (WFD) and the 2013/39/EU Directive, due to the lack of harmonized international sediment quality monitoring protocols and procedures. Most of the countries have no experience in sediment quality monitoring because it was not a routinely monitored matrix for any environmental assessment. The lack of relevant experience is particularly soaring in the transnational DRB where contamination propagation is often a transboundary problem.

Stemming from the above facts there is a territorial need in all the Danube Transnational Programme (DTP) countries to build and sustain a DRB-wide harmonized transnational sediment quality monitoring network in order to mitigate hazardous substances water pollution. Fundamentally, Danube countries need help in solving this task in a harmonized way. Moreover, DTP countries have different existing national methodologies and legislative frameworks (EU and non-EU members) for water quality assessment and monitoring. The availability of DTP countries' relevant technological capacities and resources for sediment quality monitoring implementation differs a lot. The most suited way to build a harmonized sediment quality monitoring network is a transnational cooperation to share the Danube-wide knowledge represented by the experience of SIMONA partnership in order to establish the protocols, tools, services and skills. The SIMONA project delivers 'ready-to-deploy' transnationally harmonized protocols and the SIMONA-tool to support the RBMPs in DTP countries that may serve as a basis for assessing the strategic quality of transnational cooperation projects.

The SIMONA partnership has 17 full partners (11 ERDF, 4 IPA, and 2 ENI) and 12 ASPs, which is strongly balanced and representative of the almost whole geographic Danube River Basin from the following countries: Austria, Bosnia and Herzegovina, Bulgaria, Croatia, Germany, Hungary, Moldova, Montenegro, Romania, Serbia, Slovakia, Slovenia and Ukraine.

Keywords: *Danube River Basin, monitoring, sediments, hazardous substances, harmonisation*

Mineralogical-Petrological Analysis of Lithic Artefacts from Archaeological Locality Stari Perkovci-Debela Šuma (Croatia)

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During archaeological excavations in 2006 on the Debela šuma locality situated on the Đakovo-Sredanci highway route, NE of Stari Perkovci village, approximately 190 lithic artefacts were found. Most of them belong to Neolithic Sopot Culture, whereas five are Starčevo Culture artefacts. The aim of the present study was determination

of mineralogical and petrological characteristics of stone artefacts. These characteristics are the key for determination of the geological provenance of the stone artefacts. Understanding of the provenance is useful for archaeological studies of cultural interactions and general directions of movements. Since pieces of stone tools are important archaeological findings, it is of utmost importance that the minimal amount of material is destroyed for the purpose of analysis. Therefore, preliminary analysis consisted of macroscopic determination of colour and texture. Unfortunately, macroscopic appearance of some completely unrelated stone tools is remarkably similar and it is only by detailed analysis that they can be distinguished. Moreover, macroscopic texture and colour can be deceiving as inner colour and texture may or may not be similar to the surface properties. Almost all of analysed stone tools have fine to very fine-grained texture which made even microscopic analysis very difficult. In order to additionally distinguish tools made from different rock materials specific gravity was measured. Based on macroscopic investigation 44 stone tools were selected as representative for non-destructive phase analysis of tools' surface by X-Ray diffractometer equipped with multilayer parabolic mirror. Nine of those were chosen for more detailed analyses that included polarized transmitted-light microscopy, classic X-ray powder diffraction, and a whole rock chemical composition characterization by ICP-MS/ICP-ES methods. Determined rock types that were commonly used for the production of the studied stone tools were hornfels, chert, tuffite, metadiabase and amphibole-bearing schist. One stone tool finding stands out, it was determined to be nephrite. This was not in any way obvious by macroscopic appearance, primarily due to its white colour (Fig. 1), and only a detailed analysis enabled determination of this rare and, in Neolithic context, very valuable material. Although in thin-section beside dominant tremolite some darker veinlets are visible, no other phases were determined by XRD.

Figure 1. Photograph of Sopot Culture nephrite adze from Debela šuma archaeological locality.

Nephrite was valued material in the Neolithic because of its extreme toughness and relatively low hardness. Nevertheless, their findings in European archaeological sites are relatively rare most likely due to a geological scarcity of this material in Europe. According to PÉTERDI et al. (2014) and references therein, known primary occurrences of nephrite are in the Alps (Switzerland, Italy, France, Germany and Austria), the Apennines, the Harz Mts., along the boundaries of the Bohemian Massif (in Poland and Germany), and in Scandinavia. Redeposited nephrite has been found among glacial erratics on Rügen Island and in the environs of Potsdam and Leipzig, and in the alluvium of the river Mur between Leoben and Graz. A significant number of polished tools made of nephrite has been found on the Balkan Peninsula, however a potential geological source has not been found yet. In spite of a relatively small available research database for nephrite artefacts, it was possible to classify the nephrite from Debela šuma as serpentinite-related nephrite. Geoarcheologically, the most interesting contribution of this finding is that there is no known nephrite deposit in Croatia, which means that this artefact either came from somewhere very far or there were/are some nephrite occurrences, so far unknown, in Croatia or in the neighbouring countries.

Keywords: geoarchaeology, Debela šuma – Stari Perkovci, Neolithic, lithic artefacts, nephrite

References

PÉTERDI, B., SZAKMÁNY, G., JUDIK, K., DOBOSI, G., KASZTOVSZKY, Z., SZILÁGYI, V., MARÓTI, B., BENDŐ, Z. & GIL, G. (2014):Petrographic and geochemical investigation of a stone adze made of nephrite from the Balatonőszöd – Temetői dűlő site (Hungary), with a review of the nephrite occurrences in Europe (especially in Switzerland and in the Bohemian Massif). Geological Quarterly, 58 (1), 181-192.

A New Workflow for 3D Geological Modelling of Karstfied Petroleum Reservoirs

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The accurate representation of karst features in 3D geological models is essential for obtaining reliable oil production curves from fluid flow simulation. In order to achieve that, it is mandatory to define first a conceptual model for the karst system in study, by the integration of multiple data, such as seismic, well logs, core, etc.

Petrobras developed in partnership with Emerson, a software plugin for SKUA named KarstModel, which aims not only the 3D geological modelling of karstified petroleum reservoirs, but also to guide its users to define karst conceptual models for the modelled reservoirs. This plugin is an evolution and improvement from the original KarstMod plugin developed by the GOCAD Consortium.

Cave geometry is strongly influenced by climate, and more directly, by the seasonal variation of fluid flow in subsurface. The definition of the ancient phreatic water level, the paleoclimate, the occurrence of aquitards, the distribution of porosity and permeability of the rock-fluid system, the discrete fracture network, and also the spatial position of entry/exit points of fluids in the karst system are some of the elements used by KarstModel to constrain the karst geometry.

Karst modelling is done in two phases: (1) building of the karst skeleton based on the definition of the most probable trajectory of the karstfying fluid, and (2) building of the wrapping surface of the previously built karst skeleton, through the ODSIM technique (Object Distance Simulation). Once the wrapping surface is generated by KarstModel, it can be used to estimate what percentage of the model cells are karstfied and present petrophysical properties different from the rock matrix. Besides this, the 3D models can be used as images that represent the reservoir conceptual model, and as training images for the definitive 3D reservoir modelling.

Keywords: *karst, carbonate, reservoir modelling*

Mineralogy, Geochemistry and Magmatic Provenance of Miocene Tuffs from the Dinarides and Adjacent Basins – Evidences for Mantle Upwelling?

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In the Dinarides a vast system of intramontane lakes, usually referred to as the Dinaride Lake System (DLS) came into existence in the early Miocene (KRSTIĆ et al., 2001; MANDIC et al., 2012). The DLS affiliated lacustrine environments extended northwards even into adjacent areas of the Pannonian Basin (MANDIC et al., 2019a). Consequently, at its maximum extent, coinciding with the middle Miocene Climatic Optimum, a range of freshwater or brackish to marine depositional conditions established across the area (DE LEEUW et al., 2012; PAVELIĆ & KOVAČIĆ, 2018). The entire region was affected by intensive magmatic activity, which resulted in the deposition of numerous tuff horizons interlayered with lacustrine and marine sediments. This study aims to unravel the mineralogical and geochemical proxies of the tuffs, whose age was radiometrically and stratigraphically determined to span

from 18 to 12.5 Ma (DE LEEUW et al., 2012; MANDIC et al., 2019b), in order to report on their nature, provenance and overall diversity in the context of early to middle Miocene evolution of the region that included basin infill, lakes evolution, marine transgression, sea-level lowering, and tectonic uplift.

In total 18 tuff samples were recovered from eight lacustrine and marine basins located in the realms of Pannonian Basin and Dinarides, stretching from the Styrian Basin in Austria to the Gacko Basin in Bosnia and Herzegovina. Tuffs are commonly intercalated between freshwater marls, limestones and clastic sediments, with the exception of the Ugljevik locality in NE Bosnia and Herzegovina whose tuffaceous layers were deposited in marine conditions established after the Badenian transgression (MANDIC et al., 2019b).

Analyzed pyroclastic material belongs to vitro-crystalloclastic tuffs with a characteristic porphyric texture and homogenous structure. Most of the samples are highly altered, which gave rise to the formation of clay matrix containing preserved contours of volcanic glass. Solely one sample is relatively fresh with abundance of pristine glassy shards, whereas for two samples the abated alteration led to palagonitization. Tuff mineralogy is dominated by illite-smectite clay minerals with quartz, muscovite, biotite, plagioclase, K-feldspar and amphibole being the minor phases.

Chemical composition of tuffs is featured by low amounts of K (K_2O = 0.34-3.19 wt.%) and Na (Na_2O = 0.19-1.29 wt.%), and strong variations in the content of Ti (TiO_2 = 0.07-0.97 wt.%) and Si (SiO_2 = 20.29-64.66 wt.%). The loss of ignition ranges from 6.51 to 35.84 wt.% (avg. LOI = 17.54 wt.%) indicating high level of alteration. Trace element-based discrimination diagram, Nb/Y vs. Zr/Ti (PEARCE et al., 1996), defines the majority of tuffs as intermediate rocks of trachyte, trachy-andesite and andesite composition while six samples are affiliated to rhyolitic geochemistry. Analyzed rocks display evolved and fractionated geochemical character (Mg# = 8.8-89.5; Cr = 2-118 ppm) with a pronounced enrichment of LREE over HREE [$(La/Lu)_{cn}$ = 3.76-27.89] at ~ 8-100 times chondrite relative concentrations. Negative Eu anomaly (Eu/Eu^* = 0.34-0.78) calls for an early plagioclase accumulation or fractionation at low pressure. Primitive mantle normalized curves (McDONOUGH & SUN, 1995) outline the omnipresent negative anomalies of Nb-Ta and Ti relative to La [$(Nb/La)_n$ = 0.19-1.22; $(Ti)_n$ =0.40-5.35], which indicates the subduction related magmatism that underwent a significant fractionation and possibly a continental crust contamination (Th/La = 1.8-22.61, Th/Ta = 2.03-10.89). Calc-alkaline nature of analyzed tuffs is ascertained by the use of Hf-Th-Nb diagram of WOOD (1980) and AFM plot of IRVINE & BARAGAR (1971), which conforms with the findings of ŠEGVIĆ et al. (2014) who analyzed the coeval tuffs from the Sinj Basin locating their source area in the south of the Pannonian Basin.

Preliminary results enabled identification of two distinct magmatic trends present in analyzed tuffs. First is characteristic for the ~17.04 to 14.7 Ma tuffs (radiometrically dated, DE LEEUW et al., 2012) and is featured by moderately evolved magmatism (~27-50 times chondrite concentrations, having an andesite to rhyolite composition), which tends to get more primitive with time. Second trend, spanning from ~13.86 to 12.5 Ma (stratigraphically determined, MANDIC et al., 2019b), is shown by the Ugljevik tuffs who are less evolved (~6-40 times chondrite concentrations, having predominantly andesitic composition) and are analogue to the previous group being less differentiated over time. This is tentatively explained by multiple and complex magmatic activity during early to middle Miocene (PAVELIĆ, 2001), while the steady increase in mafic character of tuffs over time may corroborate the mantle upwelling origin of Miocene volcanism in Central Europe (KOVÁCS & SZABÓ, 2008).

Keywords: tuffs, geochemistry, mineralogy, Dinarides Lake System, provenance

References

DE LEEUW, A., MANDIC, O., KRIJGSMAN, W., KUIPER, K. & HRVATOVIĆ, H. (2012): Paleomagnetic and geochronologic constraints on the geodynamic evolution of the Central Dinarides. Tectonophysics, 530-531, 286-298.

KRSTIĆ, N., DUMURDŽANOV, N., OLUJIĆ, J., VUJNOVIĆ, L. & JANKOVIĆ-GOLUBOVIĆ, J. (2001): Interbedded tuff and bentonite in the Neogene lacustrine sediments of the central part of the Balkan Penninsula. A review. Acta Vulc., 13, 91-99.

IRVINE, T.N. & BARAGAR, W.R.A. (1971): Guide to chemical classification of common volcanic rocks. Can. J. Earth Sci., 8, 523-548.

KOVÁCS, I. & SZABÓ, Cs. (2008): Middle Miocene volcanism in the vicinity of the Middle Hungarian zone: Evidence for an inherited enriched mantle source. J. Geod., 45, 1-17.

MANDIC, O., DE LEEUW, A., BULIĆ, J., KUIPER, K., KRIJGSMAN, W. & JURIŠIĆ-POLŠAK, Z. (2012): Paleogeographic evolution of the Southern Pannonian Basin: 40Ar/39Ar age constraints on the Miocene continental series of northern Croatia. Int. J. Earth Sci. (Geol. Rundsch.), 101, 1033-1046.

MANDIC, O., HAJEK-TADESSE, V., BAKRAČ, K., REICHENBACHER, B., GRIZELJ, A. & MIKINIĆ, M. (2019a): Multiproxy reconstruction of the middle Miocene Požega palaeolake in the Southern Pannonian Basin (NE Croatia) prior to the Badenian transgression of the Central Paratethys Sea. Palaeogeography, Palaeoclimatology, Palaeoecology, 516, 203-219.

MANDIC, O., SANT, K., KALLANXHI, M.-E., ĆORIĆ, S., THEOBALT, D., GRUNERT, P., DE LEEUW, A. & KRIJGSMAN, W. (2019b): Integrated bio-magnetostratigraphy of the Badenian reference section Ugljevik in southern Pannonian Basin - implications for the Paratethys history (middle Miocene, Central Europe). Glob. Planet. Chan., 172, 374-395.

McDONOUGH, W.F. & SUN, S.S. (1995): The composition of the Earth. Chem. Geol., 120, 223-253.

PAVELIĆ, D. (2001): Tectonostratigraphic model for the North Croatian and North Bosnian sector of the Miocene Pannonian Basin System. Basin Res., 13, 359-376.

References

PAVELIĆ, D. & KOVAČIĆ, M. (2018): Sedimentology and stratigraphy of the Neogene rift-type North Croatian Basin (Pannonian Basin System, Croatia): A review. Mar. Petrol. Geol., 91, 455-469.

PEARCE, J.A. (1996): A user's guide to basalt discrimination diagrams. In: Wyman DA, editor. Trace Element Geochemistry of Volcanic Rocks: Applications for Massive Sulphide Exploration. Short Course Notes 12. St. John's, Canada, Geol. Assoc. Can., 79-113.

ŠEGVIĆ, B., MILEUSNIĆ, M., ALJINOVIĆ, D., VRANJKOVIĆ, A., MANDIC, O., PAVELIĆ, D., DRAGIČEVIĆ, I. & FERREIRO MÄHLMANN, R. (2014): Magmatic provenance and diagenesis of Miocene tuffs from the Dinaride Lake System (the Sinj Basin, Croatia). Eur. J. Miner., 26, 83-101.

WOOD, D.A. (1980): The application of a Th-Hf-Ta diagram to problems of tectonomagmatic classification and establishing the nature of crustal contamination of basaltic lavas of the British Tertiary volcanic province. Earth and Planetary Science Letters, 50, 11-30.

Digital Model of the Interaction Between Natural and Hydraulic Fractures of La Luna Formation in the Middle Magdalena Valley, Colombia

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The process of hydraulic fracturing is often defined as a process which initiates and propagates fractures by applying fluid in the fracture network as a hydraulic load. The unconventional fracture model simulates the propagation, deformation and fluid flow in a complex fracture network. Interaction between natural fractures (NF) and hydraulic fractures (HF) is affected by the orientation and geometry of the natural fractures, the in-situ stress, the mechanical properties of the rock, as well as the fluid properties and layering properties (CRUZ et al., 2018; POTLURI et al., 1963; ZOBACK, 2013). The development of the geomechanical model consist in organization of data obtained from the literature and development of triaxial test in order to obtain the rocks friction coefficient and cohesion. Results are presented from a series of 2-D numerical experiments investigating the influence of natural fractures on the modelling of hydraulic fracture propagation.

Hydraulic fracturing is used for enhancing rock mass permeability and improving well productivity in low permeability reservoir rocks (KING, 2012). Geological in-situ conditions are much more complex, complicated by the presence of natural fractures and other discontinuities such as bedding planes, joints and faults (ZANGENEH et al., 2014). Further complexity arises from the heterogeneity of the in-situ stress field and anisotropy of the rock mass. OLSON (2008), presented a complex fracture network model that can predict hydraulic fracture propagation and interaction with pre-existing natural fractures. However, the model is based on fracture mechanics only and does not include fluid flow and proppant transport.

The geomechanical model needs input data to make the computer simulation, that is why the triaxial test is the best-known way to determine the cohesion and internal angle of friction in intact rocks. The test results performed on several specimens determine the failure curve. If the magnitude of environmental pressure is known, the cohesion and the internal angle of friction of the rock can be set. The software used for simulating the behavior of the fractures is ABAQUS, a suit for finite element analysis. The workflow analysis establishes several stages which include pumping, geometry of the model, constitutive model of the rock and the fractures, and fluid model along with boundary conditions.

The principal concern about this technique has to do with the environmental consequences of the fracture network propagation and length, such as pollution of the underground aquifers and induced seismicity. This study attempts to provide a technical response to this issue, using geomechanical properties from la Luna formation, an unconventional reservoir located along the MMV, to simulate the interaction of hydraulic and natural fractures to help us understand the hydraulic fracture dilemma in Colombia.

The Galembo member of La Luna formation is predominantly a calcareous shale with interbeds of thin, argillaceous limestones. The shales are hard, black, thin bedded, with numerous discoidal, ammonite-bearing limestone concretions which reach eight meters in their maximum dimension. About 63% of the volume of this formation is composed of phosphatic calcareous shales and laminated mudstones with abundant foraminifera (RANGEL et al., 2000).

The geomechanical properties of this rock are defined by BLANTON (1986) and then used by CELLERI et al. (2016) for the simulation of the interaction between NF and HF in Vaca Muerta formation of the Neuquén Basin in Argentina. The properties presented are correlated with the expected properties of the Galembo member (Table 1).

Table 1. Geomechanical properties of shales, used in numerical simulations (CELLERI et al., 2016).

Property	Units	Value
Young Modulus	Mpsi	1.45
Poisson Ratio		0.22
Fracture energy	psi*in	0.2
Shear Strenght	psi	459
Density	g/cc	1.91
Hydraulic Pressure	psi	1200
Rupture Pressure	psi	2400

This work results contribute to the understanding of the hydraulic fracturing processes and their environmental influence, considering is the first time it is done in an active basin. The issue of horizontal drilling is in a political area that is still under debate. That is why this work wants to resolve questions of Colombian society regarding the real behavior of the hydraulic fracturing. The contribution of this work will demystify issues like the capacity of hydraulic fracture to reach nearby aquifers, as well as its capacity to spread through hundreds of feet. Results of the geomechanical tests are close to being delivered, so it is not possible to show the results of the proposed simulation. The study progress has been focused on the compilation and analysis of available information on the geomechanical properties of shale rocks and the state of knowledge of hydraulic fracturing in Colombia.

Keywords: *hydraulic fracture, La Luna formation, natural fracture rock, computer simulation, shale reservoirs, geomechanical properties, unconventional reservoir*

References

BLANTON, T. L. (1986): SPE 15261 Propagation of Hydraulically and Dynamically Induced Fractures in Naturally Fractured Reservoirs.

CELLERI, H.M., SANCHEZ, M., WINOGRAD, E., ALVAREZ, J.P., SEREBRINSKY, S., HTYB, D.E. & LOPEZ, R.G. (2016): Efecto de fracturas naturales sobre la propagación de una fractura hidráulica en la formación vaca muerta, *XXXIV* (November), 8–11. https://doi.org/10.1016/0002-9149(64)90012-8

CRUZ, F., ROEHL, D. & VARGAS, E. DO A. (2018): An XFEM element to model intersections between hydraulic and natural fractures in porous rocks. International Journal of Rock Mechanics and Mining Sciences, 112 (January), 385-397. https://doi.org/10.1016/j.ijrmms.2018.10.001

KING, G.E. (2012): Hydraulic Fracturing 101: What Every Representative, Environmentalist, Regulator, Reporter, Investor, University Researcher, Neighbor and Engineer Should Know About Estimating Frac Risk and Improving Frac Performance in Unconventional Gas and Oil Wells, 1-80. https://doi.org/10.2118/152596-ms

LI, X., SHI, L., BAI, B., LI, Q., XU, D. & FENG, X. (2012): True-triaxial testing techniques for rocks – state of the art and future perspectives. True Triaxial Testing of Rocks, 2 (June 2016), 3–18. https://doi.org/10.1201/b12705

MORALES, L.G. (2016): General Geology and Oil Occurrences of Middle Magdalena Valley, Colombia, 67 (2), 249-267. https://doi.org/10.4102/ve.v33i1.685

OLSON, J. E. (2008): Multi-fracture propagation modeling : Applications to hydraulic fracturing in shales and tight gas sands.

POTLURI, N., ZHU, D., HILL, A.D. & TEXAS, A. (1963): SPE 94568 Effect of Natural Fractures on Hydraulic Fracture Propagation.

RANGEL, A., PARRA, P. & NIÑO, C. (2000): The La Luna formation: Chemostratigraphy and organic facies in the Middle Magdalena Basin. Organic Geochemistry, 31 (12), 1267-1284. https://doi.org/10.1016/S0146-6380(00)00127-3

ZANGENEH, N., EBERHARDT, E. & BUSTIN, R. M. (2014). Investigation of the influence of natural fractures and in situ stress on hydraulic fracture propagation using a distinct-element approach. Canadian Geotechnical Journal, 52 (7), 926-946. https://doi.org/10.1139/cgj-2013-0366

ZOBACK, M. (2013): Mechanical properties of shale-gas reservoir rocks – Part 1 : Static and dynamic elastic properties and anisotropy Static and dynamic elastic properties and anisotropy, 78 (September). https://doi.org/10.1190/geo2013-0050.1

Sedimentology of the Chalk Play in Norwegian Part of Central Graben, North Sea

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The Late Cretaceous to Early Paleogene Chalk Group in the Norwegian Central Graben contains prolific hydrocarbon reservoirs that have been producing for more than fifty years. Based on extensive 3D seismic and well data, development of the Chalk play with particular focus to the depositional geomorphological features is shown.

Chalk Group represents a period of high eustatic sea level and low detrital influx, leading to pelagic sedimentation on the continental shelves (VAN DER MOLEN et al., 2005). The deeply buried Chalk sediments comprise mainly chalks, chalky limestones or limestones alternating with argillaceous chalks and thin beds of shale or clays. Chalk is a porous, very fine-grained sediment deposited from suspension as a pelagic ooze in a marine setting at depths up to few hundred metres. Uplift of tectonically active areas caused occasional resedimentation of previously deposited chalk in the form of slides, slumps, debris flows and turbidity currents, commonly referred to as allochthonous chalks, and make up a large portion of the total chalk sediment package.

Extensive geological and geophysical analysis resulted in establishing key elements of Chalk play. These are: presence of an underlying mature source rock, early hydrocarbon migration into the reservoir meaning the presence of later undestroyed paleo-trap (MEGSON & HARDMAN, 2001; MEGSON & TYGESEN, 2005), preservation of the high reservoir qualities due to overburden and overpressures (MALIVA & DICKSON, 1992; GAARENSTROOM et al., 1993), favourable reservoir properties present due to the resedimentation (allochthonous chalks) and effective top seal (absence of overlying Paleocene sandstones (DE VRIES, 2014) and lateral seal (sealed by autochthonous chalks). Upper Cretaceous chalks still can be considered as one of the perspective plays in Central Graben area, especially in terms of stratigraphic trap types of prospects. Wells targeting structural traps in chalk play mainly were successful and wells targeting off-structural type of traps were all unsuccessful. Few discoveries of these kind of traps have been found in Denmark and UK parts of Central Graben.

Gravity-driven resedimentation of previously deposited chalks occasionally occurred in areas that experienced syn-depositional tectonic and halokinetic activity (VAN DER MOLEN et al., 2005; GENNARO et al., 2003). In most of the chalk fields, allochthonous chalk is the best reservoir, representing highest porosity (BRAMWELL et al., 1999). Thus, understanding of the temporal and spatial occurrence of gravity flows and related source areas is crucial to define spatial porosity variations to minimize uncertainties related to exploration in the chalk sequences.

For better understanding Upper Cretaceous chalk interval framework of 10 regional horizons was interpreted. Special attention was given to lithofacies interpretation of the available well data and seismic facies mapping. In order to connect well facies data with seismic data several different techniques of seismic analyses were used. Seismic stratigraphy approach combined with well lithofacies analysis, seismic facies analysis, amplitude analysis, Spectral Decomposition, paleo-structural mapping and source to sink method led to facies depositional mapping (FDM) and gross depositional environment mapping (GDE) that proved to be very useful in order to delineate allochthonous (reservoir) chalks. Sequences of allochthonous chalk deposits are formed in slides, slumps, debrites and turbidites.

Keywords: Central Graben, chalk play, allochthonous chalk

References

BRAMWELL, N.P., CAILLET, G., MECIANI, L., JUDGE, N., GREEN, M. & ADAM, P. (1999): Chalk exploration, the search for a subtle trap. In book: Petroleum Geology of Northwest Europe: Proceedings of the 5th Conference.

DE VRIES, N.G. (2014): Petroleum System Analysis of the Chalk Fields in the Danish and Dutch Sector of the Central Graben, North Sea. Master Thesis, Norwegian University of Science and Technology.

GAARENSTROOM, L., TROMP, R.A.J., DE JONG, M.C. & BRANDENBURG, A.M. (1993): Overpressures in the Central North Sea: Implications for trap integrity and drilling safety. In book: Petroleum Geology of Northwest Europe: Proceedings of the 4th Conference.

GENNARO, M., WONHAM, J., GAWTHORPE, R. & SAELEN, G. (2013): Seismic stratigraphy of the Chalk Group in the Norwegian Central Graben, North Sea. Marine and Petroleum Geology 45, 236-266.

MALIVA, R.G. & DICKSON, J. (1992): Microfacies and diagenetic controls of porosity in Cretaceous/Tertiary chalks, Eldfisk Field, Norwegian North Sea. AAPG Bulletin, 76 (11), 1825-1838.

References

MEGSON, J. & HARDMAN, R. (2001): Exploration for and development of hydrocarbons in the Chalk of the North Sea: a low permeability system. Petroleum Geoscience, 7, 3-12.

MEGSON, J. & TYGESEN, T. (2005): The North Sea Chalk: an underexplored and underdeveloped play. Geological Society, London, Petroleum Geology Conference series, 6, 159-168.

VAN DER MOLEN, A.S., DUDOK VAN HEEL, H.W. & WONG, T.E. (2005): The influence of tectonic regime on chalk deposition: examples of the sedimentary development and 3D-seismic stratigraphy of the Chalk Group in the Netherlands offshore area. Basin Res., 17, 63-81.

Reconstructing Holocene Vegetation in Area of Baćina Lakes

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We provide first palynological analysis of sediments from the Baćina lake Crniševo. The palynological record span thru the Holocene (c. 11300-0 cal. yr BP). In the analysed samples from the core Baj-7, we can observe the transition of vegetation in the wider studied area from a mixed forest in a moderately warm humid climate at the end of the Pleistocene to Mediterranean vegetation in the Mediterranean climate.

Changes in palynomorphs (spores, pollen, phytoplankton, and zooplankton) match with changes in geochemical parameters such as N, TOC and C/N. This congruence allowed a better interpretation of some changes as well as increase or decrease of (palynomorph) values.

There are nine zones and nine subzones that correlate to the changes in climate, vegetation, and trophicity. Samples of the oldest PZBAJ-I zone were deposited in the shallow hypertrophic lake at the time of the rapid rise in sea level (MWP-1B) before 11.3 cal. yr BP. Hypertrophic conditions also existed at the time of the PZBAJ-II zone which coincides with the onset of deposition of the sapropel S1a 10800-8800 cal BP at the beginning of the Holocene. Zone PZBAJ-III occurs in the proximal, i.e., the shallower part of the mesotrophic lake. During the zone PZBAJ-IV, the lake changes from the mesotrophic to the oligotrophic condition. Warming and the decrease of precipitation occur, and the freshwater green alga *Botryococcus braunii* appears. For the PZBAJ-V zone, remarkable is a low percentage of green algae *Coelastrum polychordum.* A gradual decrease in the share of cyanobacteria *Gloeotrichia*, as well as a noticeable share of elements of Mediterranean vegetation (*Quercus ilex* -type and *Ostrya* type) and heathers (Ericaceae), is shown. The PZBAJ-VI area is divided into six subzones where the humid and drought periods change, i.e., the secondary succession of vegetation due to the deforestation. The first subzone is PZBAJ-VIa, in which the share of Mediterranean vegetation elements generally reduces, while the proportion of deciduous vegetation increases, suggesting a more humid climate with more rainfall. But, at the beginning of the zone, there is a decrease in the proportion of deciduous oak and the increased proportion of the heathers (Ericaceae) and grass (Poaceae) which may correspond to the drought period 4200 BP. The subzone PZBAJ-VIb is dominated by amorphous liptinite of algal origin which indicates an increased primary organic production. The subzone PZBAJ-VIc shows a sudden increase in the proportion of nitrogen due to the high share of green algae *Coelastrum polychordum* and occurrence of alder (*Alnus*). There is a decreased proportion of heathers (Ericaceae) and grass (Poaceae), and an increased proportion of ferns. That indicates secondary succession that can be traced from this subzone. After the oak forests clearings (some 3500 years ago), ferns and alder appear as pioneer species followed by the fir increase, and pine increase at the end of the subzone. The oak increase occurs in the next subzone PZBAJ-VId as the vegetation is renewed. At the end of the subzone (some 3200 years ago), evidence of clearings is again evident followed by subsequent forest recovery during the subzone PZBAJ-VIe. The most intensive forest clearings (some 2200 years ago) occur during the PZBAJ-VIf subzone. And again forest is being renewed during the PZBAJ-VIIb subzone (some 1800 years ago, i.e., 200 AD). The share of pollen of trees decreases in the subzone PZBAJ-VIIc, while the proportion of algae, heathers, and grass increases, corresponding to the medieval warm period when the lake changes from mesotrophic to the eutrophic conditions, which remains to the present.

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Keywords: Holocene, palynology, climate, Croatian Adriatic coast

Geological Component of Terroir of the Nature Park Papuk Red Wines

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Within the Nature Park Papuk, especially on the southern slopes of Mt. Papuk, numerous vineyards are situated. They prograde up finding their place high on the mountain. In spite of the fact that it is already on the high quality level, wine production in the area reflects constant effort of winemakers to improve the production, aiming mostly on the quality and not only on the quantity. The scope of this contribution is to better define the geological component of a *terroir* of wine related to the specific microenvironment that evolved from metamorphic and igneous rocks. With kind help of the Nature Park Papuk, Veleučilište u Požegi and Vinarija Vlado Krauthaker sampling of rock, soil, grape and wine samples of northernmost and highest vineyards near Vetovo village was performed. The vineyards with grapes that give red wines: Cabernet Sauvignon, Merlot and Shiraz (Veleučilište u Požegi) and Syrah (Vinarija Vlado Krauthaker) are planted on a thin soil cover laying directly over the pre-Alpine crystalline basement of the Slavonian Mountains.

The crystalline rocks found as debris in the vineyards are mostly orthogneisses (Bt+Ms+Pl+Qtz+Grt) and micaschists together with amphibolite (Amp+Pl+Grt+Qtz+Bt) and metagabbro. Those rocks belong to the oldest dated rocks at Mt. Papuk (528±7 and 465±7 Ma (2σ)) with calc-alkaline peraluminous crustal and mafic rocks as precursors, respectively. They are related to a former active continental marginal setting. The calculated peak P-T metamorphic conditions reach 13 kbar and 670 °C (BALEN et al., 2015).

The soil developed on the hill slopes was sampled at two horizons: at 30–35 and 60–65 cm depths. Upper level is characterized by brown colour where sand (and grus) predominates over the clay component. This level is rich in (altered) fragments of metamorphic rocks and quartz. At 60 cm depth, dark brown clay-rich soil comprise limonite substance, metamorphic rocks fragments and agglomerates of altered amphiboles. The basement rocks outcrop through those soil layers. The deeper horizon is more acidic (pH=4.3–4.6 vs. 4.6–4.8; exchangeable acidity) which might be ascribed to the anthropogenic influence on the upper soil horizon.

Standard minerals typical for amphibolite facies, garnet, amphibole, biotite and feldspar are major hosts of elements important for the wine production. Such elements, liberated from minerals through alteration processes (i.e. production of the "clay minerals" and soil) and biochemical reactions enter the plant, grape and finally end in the wine. All chemical elements measured here are within Croatian legal normative (NN 2/2005 – 4.1.2005). The concentration of elements in the wine correlates well with the soil and mineral/chemical composition of the predominant mineral assemblage in the unaltered rocks. Among them, Ca and Mg demonstrate the best correlation between original rock and red wine. Combination and availability of Fe, Mg, Na, K and Ca together with other factors of wine production have created almost ideal combination for red wine production in this part of Nature Park Papuk.

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Keywords: *terroir, metamorphic rocks, Papuk, wine*

References

BALEN, D., MASSONNE, H-J. & PETRINEC, Z. (2015): Collision-related Early Paleozoic evolution of a crustal fragment from the northern Gondwana margin (Slavonian Mts., Tisia Mega-Unit, Croatia): reconstruction of the P-T path, timing and paleotectonic implications. Lithos, 232, 211-228.

Taxonomy and Distribution of Benthic Foraminifera and Ostracods in an Intertidal Zone of the Adriatic Sea: Lokunja Salt Marsh (Pag Is.)

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Intertidal zones due their conditional instability and great anthropogenic pressures are considered the most vulnerable and stressful ecosystems in the world. The Lokunja salt marsh, located in the town Pag (Pag Is.) and near to the salt pans, is well known by its healthy mud. Most of the areas present very shallow water depths with microtidal (0.25 m, HHI data), semidiurnal tidal regime. Once natural spit protect the area from the open sea. Four sediments samples were collected manually in July 2018. The aim of this study is to describe the composition and structure of Foraminifera and Ostracoda in detail in order to investigate the distribution of each group in this restricted environment. Micropalaeontological analyses were performed on samples washed through a 63 μm sieve and residue was then split into small proportions containing at least 300 specimens of benthic foraminifera and 200 valves of ostracods.

To characterize the biodiversity of foraminiferal assemblages, five faunal parameters were calculated: (1) species diversity and the number of species in each sample; (2) dominance, (3) Shannon-Weaver index, (4) Pielou's evenness and (5) Fisher – α index. The size frequency graphs were constructed for dominant foraminiferal species in order to recognize the status of assemblages. A total of 1038 benthic foraminifera, belonging to nine taxa, have been counted and identified. Species richness in all studied samples varies from 4 - 8, dominance shows a maximum value of 0.43, the lowest value of Shannon-Weaver index is 0.77, the lowest value of Pielou's evenness is 0.39 whereas Fisher α index reaches the greatest value of 1.59. The values of all indices suggest hyposaline, lagoonal setting. A*mmonia parkinsionana* (D'ORBIGNY) forms generally dominate the foraminiferal fauna (63 to 77%), with subordinate *Haynesina depressula* (WALKER & JACOB) (2.7-15%) and *Porosononion granosum* (D'ORBIGNY) (9.5-16%). The population of *A. parkinsoniana* is characterized by a Gaussian (normal) size distribution, peak in abundances occurred approximately at range 260-300 μm. It clearly point out that even in this restricted area certain hydrodynamic parameters occur and they control the distribution of the tests. In addition, the dominance of the opportunistic, oligohaline species confirms relatively high nutrient inputs, represented by labile and refractory organic matter. All ostracod assemblages are dominated by *Cypreides torosa* (JONES), a widespread, euryhaline taxon, commonly found in transitional environments such as lagoons, estuaries, and inland ponds. This an opportunistic species, able to live from almost freshwater to hypersaline conditions, irrespective of substratum type, vegetation cover, temperature, and oxygen concentration. *C. torosa* presents two morphotypes with different ornamentation of the valves, and both of them are recorded within this assemblage: noded and un-noded (although this type prevails). The co-dominance of noded and un-noded reflects deposition in a restricted, oligohaline environment, like a low-salinity inner lagoon possibly with oxygen deficiency, where only this opportunistic species is able to thrive. Interestingly, based on their shape and size, all found valves of *C. torosa* belonged to male individuals and along with uniform size suggest their *post-mortem* transport.

Keywords: *Ammonia parkinsoniana, Cypreides torosa, salt-marsh, size-frequency graph*

Palynology of a New Lower Pannonian (Upper Miocene) Reference Section from the Transylvanian Basin (Romania)

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The Transylvanian Basin located in the eastern segment of the Pannonian Basin System (PBS) provides an excellent insight into the early evolution of Lake Pannon. Lower Pannonian deep-water deposits, which are often buried deep in the Hungarian and Croatian part of the PBS are exposed on the surface. Despite the stratigraphic significance and rich fauna, a systematic palaeontological and biostratigraphic evaluation, including palynology, has not been carried out yet. The detailed multiproxy analysis (palaeontology including palynology, magnetostratigraphy and authigenic $^{10}Be/^{9}Be$ dating) of the Guşteriţa section fills a significant gap in the chronostratigraphic assessment of the Pannonian stage in Transylvania.

The Guşteriţa clay pit near Sibiu exposes a continuous deep-water lower Pannonian section. The outcrop encompasses a 55 m thick section of grey laminated or massive marl and silty marl layers with fine-very fine-grained cross-laminated sand intercalations. The section hosts a rich fossil assemblage, including molluscs, ostracods, thecamoebians, fish teeth, otoliths, some partial fish skeletons, and fossil plants.

Besides molluscs typical for *Congeria banatica* beds, organic-walled microplankton assemblages with dinocysts in particular, represent a powerful tool for biostratigraphic subdivision within the PBS. After the connection to the Eastern Paratethys and the Mediterranean region ceased around 11.6 Ma ago, Lake Pannon was formed in the Central Paratethys area. The brackish-water conditions initiated a remarkable radiation among organic-walled dinoflagellates. The isolated evolution of these dinocysts resulted in rapid morphological changes, which formed the basis of several regional biozonation schemes developed for the Hungarian and Croatian part of the PBS (e.g., SÜTŐ-SZENTAI, 2000; BAKRAČ et al., 2012).

A total of 25 palynological samples have been collected from the uppermost 25 metres of the quarry. The samples reveal a moderately diverse, but excellently preserved dinocyst assemblage and several other aquatic (acritarchs & green algae) and terrestrial palynomorph groups (spore & pollen). The majority of the dinocysts are endemic Pannonian taxa, e.g. *Spiniferites pannonicus*, *Spiniferites oblongus,* and various species of the genus *Virgodinium*, *Impagidinium,* and *Pontiadinium*. The Guşteriţa dinocyst assemblages resemble those of *Spiniferites bentorii oblongus* biozone and the *Pontiadinium pecsvaradensis* biozone from the Hungarian part of the PBS. The biostratigraphic correlation suggests an age range between 11.0 and 10.6 Ma. This age assignment agrees with the magnetostratigraphy that placed the section into the C5n.2n long normal polarity magnetic chron (11.056-9.984 Ma, ATNTS2012). Similarly, the calculated age from authigenic $^{10}Be/^{9}Be$ isotopic dating provided an age of 10.84 ± 0.4 Ma.

The large amount of terrestrial palynomorphs and reworked older Miocene taxa (e.g., *Polysphaeridium zoharyi*, *Cleistosphaeridium placacanthum* and *Melitasphaeridium* sp.) indicates intense erosion and runoff into the lake from the adjacent hinterland.

Abundant bisaccate conifer pollen and *Tsuga* (hemlock) represent extrazonal vegetation elements originating probably from the emerging mountains around the lake. *Carya* (hickory) and *Tilia* (linden) are characteristic elements of a warm-temperate mesophytic broad-leaved deciduous forests, while the high abundance of Taxodiaceae pollen indicates the presence of swamps along the shore.

The new data also reveal the palaeogeographical connections between the Transylvanian Basin and other areas of the PBS which ceased by ca. 9 Ma ago. The integration of the new biostratigraphic subdivision with magnetostratigraphy and authigenic $^{10}Be/^{9}Be$ isotopic dating represent a significant improvement of the regional Pannonian chronostratigraphy and its correlation to the global time scale.

Keywords: *Neogene, Pannonian, Transylvanian Basin, biostratigraphy, palynology, dinoflagellates*

References

BAKRAČ, K., KOCH, G. & SREMAC, J. (2012): Middle and Late Miocene palynological biozonation of the south-western part of Central Paratethys (Croatia). Geologica Croatica, 65/2, 207-222.

SÜTŐ-SZENTAI, M. (2000): Organic walled microplankton zonation of the Pannonian s. l. in the surroundings of Kaskantyú, Paks and Tengelic (Hungary). Annual Report of the Geological Institute of Hungary 1994–1995, 153-175.

Salt Pans from Dalmatia, Croatia, as New Sea-Level Proxy for the Last 2 ka

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Paleo relative sea-level (RSL) in the Mediterranean is based on archaeological biological and sedimentological observations which are not always in agreement. Among the archaeological indicators fish tanks are considered the most reliable but they also need determination of their functional height for evaluating past sea levels (LAMBECK et al., 2004, 2018; EVELPIDOU et al., 2012)

Saltpans like fish ponds are also intertidal facilities, used for the last 2000 years in the Mediterranean (MARK, 2002; MARZANO, 2013). The Eastern Adriatic Sea, focusing this time on the Dalmatian shore, contains large number of preserved and historically dated ancient saltpans, now flooded by the rising sea (DOKOZA, 2015), providing great potential for RSL indication.

The primary objective of the study is to develop a new holistic approach combining multi-image photogrammetric techniques for high quality elevation measurements of the saltpans structures and estimating paleo RSL during the last 2 ka with sedimentological analysis for identification of the depositional conditions.

The study includes three selected sites: Makirina bay, Brbinj in Dugi Otok, and Lavsa Island, Kornati. It combined areal photogrammetry, bathymetry acoustics scanning, underwater archaeological survey of the man-made structures. Wood and mortar was sampled for dating and for defining the original environmental conditions of the saltpans at the time of construction; marine or terrestrial. In addition, short cores (up to 2m) were drilled in the inner bay where the saltpans existed aiming to determine the transition from terrestrial/lagoon conditions to hipper saline saltpans and then to sea water coverage. These transitions intend to be dated indicating the time and elevation of the transition from natural conditions to anthropogenic and back to natural when sea level finally flooded the saltpans.

Once the combined approach will be established, it has the potential of becoming a significant tool for estimating RSL for the last two millennia in the Eastern Adriatic Sea, Central Mediterranean.

Keywords: *Saltpans, Archaeological sea-level markers, Digital terrain and underwater modeling, sedimentary characteristics, Dalmatian coast*

References

DOKOZA, S. (2015): The Nobility of Zadar and Salt during the Second Half of the 14th and the Early 15th Century. Povijesni prilozi, 49(49), 86-123.

EVELPIDOU, N., PIRAZZOLI, P., VASSILOPOULOS, A., SPADA, G., RUGGIERI, G. & TOMASIN, A. (2012): Late Holocene Sea Level Reconstructions Based on Observations of Roman Fish Tanks, Tyrrhenian Coast of Italy. Geoarchaeology, 27(3), 259-277.

LAMBECK, K., ANZIDEI, M., ANTONIOLI, F., BENINI, A. & ESPOSITO, A. (2004): Sea level in Roman time in the Central Mediterranean and implications for recent change. Earth Planet. Sci. Lett., 224, 563-575.

LAMBECK, K., ANZIDEI, M., ANTONIOLI, F., ALESSANDRA BENINI, A. & VERRUBBI, V. (2018): Tyrrhenian sea level at 2000 BP: evidence from Roman age fish tanks and their geological calibration. Rendiconti Lincei. Scienze Fisiche e Naturali, 1-12.

MARK, K. (2002): Salt: A World History. Walker and Co., New York.

MARZANO, A. (2013): Harvesting the Sea. The Exploitation of Marine Resources in the Roman Mediterranean 2013 Oxford.

The Protholite Age of Greenschists of Medvednica Mt. (NW Croatia)

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The Medvednica Mt. is located in the north-western Croatia, in the Zagorje-Mid-Transdanubian Shear Zone, in the junction area of geotectonic units Alps, Tisza and Dinarides. The main greenschist mass is found in the central part of Medvednica Mt. (Malo and Veliko Sljeme – Puntijarka), while small occurrences, in the form of tectonic zones and in the sinsedimentation position with metasediments could be found in the north-eastern part of Medvednica Mt., stretched from the village Mikulić in the southwest to the Blaguša stream north of Kobiljak locality.

According to the preserved relicts of the ophitic structure and greenschist geochemical analysis, basalt and diabase with characteristics of enriched N-MORB, have been confirmed to be the protholite rocks. Metamorphic changes were created by subduction-collision processes from middle Jurassic to Lower Cretaceous in the greenschists facies, at temperatures from 350 °C to 450 °C and pressure of 3 to 4 kbar.

The greenschist of Medvednica Mt. is closely associated with different lithostratigraphical units of metasediments:

1) The main greenschist mass is associated with metaradiolarite, quartz-chlorite schist, and thinner interlayers of ankeritized metacarbonate. Fossiliferous content in rocks (radiolaria and filaments) didn't allow the protholite age stratigraphic determination of *parametamorphites.* In the Alps-Dinaric region, from the lithofacies point, the protholite rocks could be positively correlated with the Middle-Upper Triassic and Jurassic lithofacies.
2) The greenschist interlayered with recrystallized limestone. The recrystallized limestone is determined as middle Triassic, Anisian (Bithynian-Illyrian) on the basis of the conodonts.
3) Small greenschist bodies associated with the dark metapsamites, black calcitic metapelites and black silty recrystallized limestones. In the recrystallized black limestones, conodonts are typical for the Upper Ladinian (Upper Longobardian) - Lower Carnian (Cordevolian).
4) The greenschist (metadiabase) associated with the metamorphosed limestone and the dark metapelite. Based on conodonts and graptolite metasedimentes, Paleozoic age was determined. Greenschist protholite is diabase, assumed to have been created in Permian-Triassic synrift phase.

The protholite rocks (basalt and diabase) age for certain greenschists were determined to be Middle Triassic, Anisian (Bithynian-Illyrian) and Upper Ladinian (Upper Longobardian) – Lower Carnian (Cordevolian). Basalt, the protholite rocks of the main greenschist mass of Medvednica Mt. is assumed to be Middle-Upper Triassic or Jurassic age. The geotectonic position of greenshist protolite rock could be connected to the magmatic activity during the synrift Triassic phase and to the formation of western Tethyan oceanic realm.

Keywords: *Medvednica Mt., greenschists, protholite age, Conodonts, Radiolarians*

Establishment of a Basic Interactive Interpretation and Data Correlation System (IIDCS) at the Croatian Geological Survey

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Modelling of Geological Basins is typically based on integration of deep seismic and borehole data. In order to have systematically arranged data needed for the interpretation and modelling, it requires establishment of a basic Interactive Interpretation and Data Correlation System (IIDCS).

The establishment of a basic Interactive Interpretation and Data Correlation System (IIDCS) at the Croatian Geological Survey is one of the main goals of the GeoTwinn project. GeoTwinn is a Horizon 2020 project intended and designed to twin the Croatian Geological Survey (HGI-CGS) with two world-leading geoscience research institutes; the Geological Survey of Denmark and Greenland (GEUS) and the British Geological Survey of the United Kingdom Research and Innovation (BGS-UKRI), leading to significantly strengthen HGI-CGS's research collaboration (http://projects.hgi-cgs.hr/geotwinn/). GeoTwinn project consists four Work Packages (WPs); (1) 3D geological surveying and modelling, (2) advanced groundwater flow and contaminant transport modelling, (3) geological hazards, and (4) geothermal energy.

The IIDCS is built primarily for the GeoTwinn project, and will be used for the interpretation of geophysical and geological data, the advanced reservoir modelling, and finally, for building an Initial 3D reservoir-properties model for the greater Zagreb area. It is also the intention of GeoTwinn to use the IIDCS for introducing the digital storage, organization and management of all kinds of geophysical, geological and petrophysical data available at the Croatian Geological Survey.

Geological modelling of the greater Zagreb area and its deep geothermal aquifer is the main objective of WP1. The model is to be used for modelling of geochemical processes, and fluid and heat flow modelling in the WP4. Zagreb geothermal aquifer is situated inside Triassic dolostones and dolomitic limestones, and Badenian bioclastic limestones of the Vrapče formation. Well data shows that geothermal aquifer lays in depths between (approx.) 800 to 900 meters, and seismic data shows very complex structural and stratigraphic relations. The bottom and the base of aquifer were mapped using Halliburton Landmark DecisionSpace Geoscience software, and the data was stored into the Interpretation and Data Correlation System (IIDCS) using Halliburton Landmark OpenWorks database.

Keywords: *Interactive Interpretation and Data Correlation System Geological modelling, Zagreb geothermal aquifer, GeoTwinn*

Recent and Submerged Tombolo on Prvić Island, Kvarner Area

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The tombolo is a depositional geomorphological form (sandbar, barrier or spit) that joins an island or a barrier with the mainland or another island, resulting from longshore drift or the migration of an offshore bar toward the coast (WARD, 2004). Two tombolos, recent and submerged, are on the south-western coast of Prvić Island (Kvarner area, the north-eastern channel part of the Adriatic Sea).

Three geomorphological factors are important for the origin of these tombolos: specific geological fabric, oceanographic conditions and sea-level change during Holocene.

Prvić Island is mostly formed in carbonate rocks consisting of Upper Cretaceous and Palaeogene carbonate rocks, and partially of Palaeogene siliciclastic rocks (MAMUŽIĆ et al., 1969). Most of the island has a typical karstic landscape. The investigated area close to Cape Pipa is located in the central part of the south-western coast. The coastal relief and geologic fabric are very different in relation to other coastal parts of this island. There Palaeogene flysch bedrock is partially covered by Quaternary sediments. This sediment body has a form of irregular triangle with a base length of approximately 50 m. The height of this deposit is 10 to 12 m. The stratification is well visible in the sediment body, where silty sand prevails. Some layers contain angular fragments and blocks from carbonate rock mass. Cape vertex itself is formed of collapsed blocks of talus breccia and provide an obstacle to wave motion. Beach sediment body connects the cape vertex with the coast. Wind waves from the northwest (tramuntana) and southeast (jugo) generate longshore currents, which are responsible for coastal erosion and accumulation of sediment in the beach bodies. Recent tombolo is in a state of equilibrium in the present climatic and oceanographic condition.

Much bigger triangular tombolo form is clearly visible on the sea bottom, southeast from Cape Pipa. Paleo-coastline is approximately 300 m long. Unusual dark parallel lines are clearly visible on the ortho-photo image, where these submerged outcrops look like artificially built walls. The exploration by scuba-diving has revealed that they are outcrops of more resistant sub-vertical layers within the flysch rock mass. Concave traces of ancient coast are clearly visible on the western side and less noticeable on

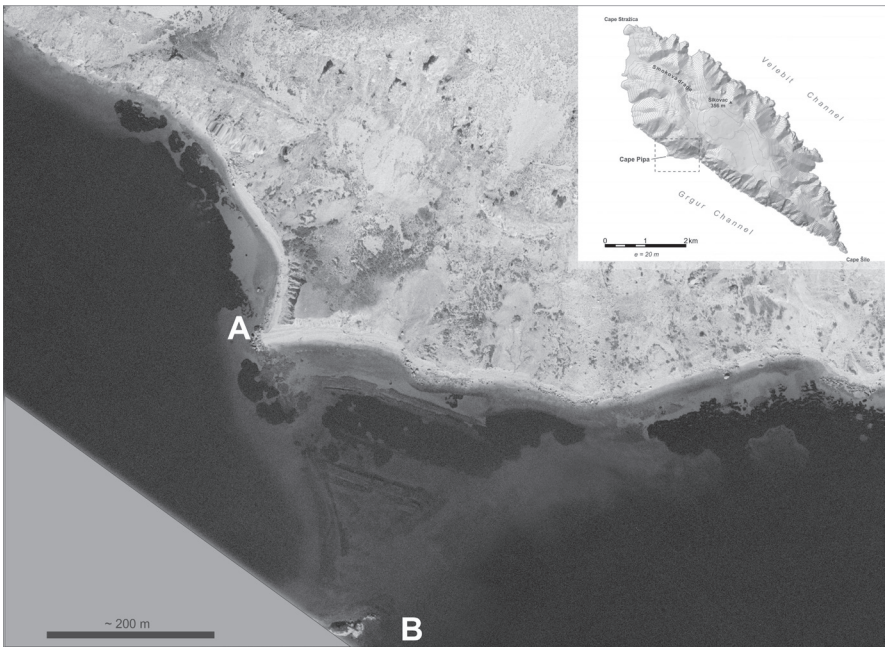

Figure 1. Location map and ortho-photo image of recent and submerged tombolo: A-Cape Pipa, B-the Njivice Rock.

the south-eastern side. This submerged tombolo form was formed behind another obstacle, and it is located at depths up to 10 m. The Njivice Rock is built of relative resistant carbonate breccia.

The conditions for forming a submerged tombolo could have occurred during the sea-level rise during the late Pleistocene and Holocene (SURIĆ, 2009; TSIMPLIS et al., 2009). The sea has flooded the submerged tombolo probably in the last phase of rapid sea-level rise at the beginning of Holocene. A large part of less resistant Quaternary sediments and fine-grained flysch rock mass were eroded. Njivice Rock played an important role in the formation of the tombolo. This rock provided an obstacle to waves in the shallow and flattened area.

Two generations of tombolos co-existing at close proximity is a unique phenomenon in the Adriatic Sea, and possible in the Mediterranean Sea.

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Keywords: *tombolo, marine erosion, sea-level, Holocene, Adriatic Sea*

References

MAMUŽIĆ, P., MILAN, A., KOROLIJA, B., BOROVIĆ, I. & MAJCEN, Ž. (1969): Osnovna geološka karta SFRJ 1:100.000, list Rab L 33-114. [Basic Geological Map of SFRY 1:100.00, Rab sheet – in Croatian]. Institut za geološka istraživanja, Zagreb. Savezni geološki zavod, Beograd.

SURIĆ, M. (2009): Reconstructing sea-level changes on the Eastern Adriatic Sea (Croatia) – an overview. Geoadria, 14 (2), 181-199.

TSIMPLIS, M.N., RAICICH, F., FENOGLIO-MARC, L., SHAW, A.G.P., MARCOS, M., SOMOT, S. & BERGAMASCO, A. (2009): Recent developments in understanding sea level rise at the Adriatic coasts. Physics and Chemistry of the Earth. Parts A/B/C, 59-71.

WARD, S. (2004): Tombolo. In: GOUDIE, A.S. (ed.): Encyclopedia of geomorphology. Rutledge, IAG, London – New York, 1054 p.

Correlation of Tuff Intervals in Syn-Rift Sediments of the Western Part of the Drava Depression, North Croatian Basin

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The syn-rift phase of the extensional tectonics that formed the North Croatian Basin and the Drava Depression within it lasted from Ottnangian to Middle Badenian age (e.g. PAVELIĆ, 2001, PAVELIĆ et al., 2018). Complex changes in the syn-rift depositional environments during the extension were documented by well cores, well log suites and 3D seismic data. Half-graben continental successions of coarse-grained siliciclastics are often interlayered with volcanic sequences. Their petrologic data are in accordance with the well log analyses that reveal high gamma-ray values and low bulk density values in acidic volcanic rocks vs. generally opposite values in the parts of volcanic successions determined by petrologic analyses as andesite-basaltic rocks. Gamma-ray logs often show cyclic responses that could reflect multiple extrusive events. This study is a part of the current PhD work and presents the correlation of the volcanic intervals from ten wells drilled in the western part of the Drava Depression, as well as the interpreted 3D seismic sections with their position in the half-graben successions. Reworked volcaniclastic and mixed volcaniclastic-siliciclastic deposits represent a minor, although common part of the half-graben infill in the study area.

Sedimentological features of some of these sequences suggest their emplacement by braided streams and conglomeratic alluvial fans, which is common in the earliest deposits of the NCB (PAVELIĆ et al., 2018). Outcrop tuff analyses (MARKOVIĆ, 2017) report both neutral and acidic tuff successions in the localities in the Slavonian Mts., Medvednica Mt. and Banovina region. Pyroclastic sediments from alluvial deposits of near-by Kalnik Mountain were dated on 18 Ma, i.e. Ottnangian age (MANDIĆ et al., 2012). The lack of biostratigraphic and radiometric data in the study area poses questions about the stratigraphic position of these deposits, although they could be correlated with very similar sedimentary successions that were studied from the outcrops of the Slavonian Mountains (e.g. PAVELIĆ, 2001; MARKOVIĆ, 2017).

Keywords: *tuff, correlation, half-grabens, Drava depression*

References

MANDIĆ, O., DE LEEUW, A., BULIĆ, J., KUIPER, K.F., KRIJGSMAN, W. & JURIŠIĆ-POLŠAK, Z. (2012): Paleogeographic evolution of the southern Pannonian Basin: 40Ar/39Ar age constraints on the Miocene continental series of northern Croatia. Int. J. Earth Sci., 101, 1033-1046.

MARKOVIĆ, F. (2017): Miocene tuffs of the North Croatian Basin. Unpubl. PhD Thesis, Faculty of Science. University of Zagreb, 170.

PAVELIĆ, D. (2001): Tectonostratigraphic model for the North Croatian and North Bosnian sector of the Miocene Pannonian Basin System. Basin Res., 13, 359-376.

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. (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.

Early Miocene Alluvial Fans on the Northern Margin of the Drava Depression, North Croatian Basin

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This study focuses on the alluvial fan facies characteristics and their spatial distribution in the eastern part of the Drava depression, i.e. on its northern margin. A number of smaller, asymmetrical half-grabens developed during the syn-rift phase, thus forming the sub-depressions elongated in NW-SE direction which acted as Early – Middle Miocene depocenters (PAVELIĆ & KOVAČIĆ, 2018). Sedimentary successions described from the well cores directly reflect the tectonic activity of the half-graben bounding normal and listric faults developed through the early rifting stages in the evolution of the Drava depression. The described sediments belong to the Mosti Member, Moslavačka Gora Formation and are important HC reservoirs in the Drava Depression (e.g. MALVIĆ & VELIĆ, 2011).

As a part of the PhD research, alluvial fans were mapped in the 3D survey as moderate to high-amplitude reflectors delineating wedge-shaped sedimentary bodies with internal seismic facies consisting of hummocky and almost chaotic reflections. NW-SE seismic sections show roughly lobate, overlapping, amalgamated sedimentary bodies comprising several episodes of alluvial fan development. Interpreted perpendicular sections reveal general N-S to NNE-SSW sediment transport direction, which is in accordance with analysed clast provenance.

The main constituents of the studied sedimentary successions are breccias, matrix-supported, poorly sorted, rarely clast-supported conglomerates as the products of debris flow and occasionally conglomeratic sandstones with mudstones probably deposited as sheetfloods or flood flows. A large number of sedimentological models of recent and palaeo-fans in arid and semi-arid rift valleys that comprise the outcrop (e.g. PAVELIĆ & KOVAČIĆ, 1999; PAVELIĆ, 2001) and subsurface data set, i.e. 3D reflection seismic, well core and well log data define the models of alluvial fan development. Similar sediments were described in this study based on sedimentological analyses showing the prevalence of coarse-clastic deposits, post-depositional alterations as oxidation, occurrence of calcrete, lack of preserved fossils and the geometry of alluvial fans revealed in analysed seismic sections.

Keywords: *alluvial fans, coarse clastics, half-grabens*

References

MALVIĆ, T. & VELIĆ, J. (2011): Neogene Tectonics in Croatian Part of the Pannonian Basin and Reflectance in Hydrocarbon Accumulations. In: SCHATTNER, U. (ed.): New Frontiers in Tectonic Research: At the Midst of Plate Convergence, InTech, 215-238.

PAVELIĆ, D. & KOVAČIĆ, M. (1999): Lower Miocene alluvial deposits of the Požeška Mt.(Pannonian Basin, northern Croatia): cycles, megacycles and tectonic implications. Geol. Croat., 52, 67-76.

PAVELIĆ, D. (2001): Tectonostratigraphic model for the North Croatian and North Bosnian sector of the Miocene Pannonian Basin System. Basin Res., 13, 359-376.

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.

Early Miocene Lake Successions in the Drava Depression, North Croatian Basin

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The late phase of the early continental syn-rift deposition in the North Croatian Basin, Pannonian Basin System, was described from a number of surface localities in the Drava Depression (e.g. PAVELIĆ & KOVAČIĆ, 2018). Coarse grained delta successions cropping out on the Požeška Mountain were described as Gilbert-type deltas with a primary sedimentary dip of 30° that prograded into the large, hydrologically open lake (PAVELIĆ, 2001; PAVELIĆ et al., 2016). Similar geomorphological features, i.e. prograding clinoforms, were detected during current PhD research in the Drava depression with the focus on mapping of syn-rift successions. Interpreted seismic sections highlight the main structural features of the syn-rift phase in the Drava depression and its subdepressions. These elongate depocenters are bounded by the main NW-SE striking listric and normal faults with minor NE-SW striking and SE dipping faults. Listric normal faulting and the southward backstepping of the fault escarpment are the main extensional features in the Drava Depression (PAVELIĆ & KOVAČIĆ, 2018). The main faults defined the basin margins and controlled the deepening of the depocenters during the syn-rift phase. One of the deepest early Miocene depocenters is situated in the central to eastern part of the Drava depression. Two subdepressions merge there into the area with significantly larger tectonic subsidence. It provided accommodation space big enough for coarse-grained deltas to develop, forming successions of more than 300 m of freshwater sediments.

Well core data from several wells in the study area reveal the following lithofacies succession: the oldest sediments that overlie the basement are conglomerates and debrite breccias, followed by thin layers of sandstones, siltstones and marls, occasionally interlayered with tuff. Fossils are rare and are mainly represented by ostracods and only a few mollusc shells and gastropods. Fragments of oxidized plant fragments are more common. Similar sediments, occasionally with analcime, were already reported from the Papuk Mountain (e.g. ŠĆAVNIČAR et al., 1983). Transition from alluvial sediments to the fine-grained lake sediments is nicely visible at the Banićevac location, Psunj Mountain.

This study shows good correlation between the data provided by these outcrop studies and the subsurface data from several deep exploratory wells.

Keywords: *syn-rift, depocenters, lake*

References

PAVELIĆ, D. (2001): Tectonostratigraphic model for the North Croatian and North Bosnian sector of the Miocene Pannonian Basin System. Basin Res., 13, 359-376.

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., BANAK, A., JIMENEZ-MORENO, G., MARKOVIĆ, F., PIKELJ, K., VRANJKOVIĆ, A., PREMUŽAK, L., TIBLJAŠ, D. & BELAK, M. (2016): Early Miocene European loess: A new record of aridity in southern Europe. Geol. Soc. Am. Bull., 128, 110-121.

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.

ŠĆAVNIČAR, S., KRKALO, E., ŠĆAVNIČAR, B., HALLE, R. & TIBLJAŠ, D. (1983): Analcime bearing beds in Poljanska. Rad JAZU, 404, 137-169.

A Report on the Well-Preserved Miocene Volcanic Cone from the Drava Depression, North Croatian Basin – Inference from the Deep Seismic Reflection Data

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The large volume of effusive volcanic rocks and pyroclastites in the Drava Depression indicates a close interplay between the magmatism and extensional tectonic activity during Lower to Middle Miocene (e.g. PAVELIĆ, 1998, PAVELIĆ & KOVAČIĆ, 2018). These findings are in accordance with the well-core data from numerous wells in the Drava depression. Volcanic breccias, andesitic-basaltic lava flows, as well as different types of acidic pyroclastic rocks (e.g. ash fall tuffs, pyroclastic flows) were reported from the cored syn-rift successions, but so far without research on the possible volcanic source areas.

This study presents the first example of a preserved volcanic cone obtained from deep seismic reflection data and supported by the well data.

Eroded volcanic features were inferred from the exposed volcanic successions only in one surface location near the study area. Lower Miocene volcanic activity was documented in the area of Mt. Krndija in the Slavonian Mountains (PAMIĆ et al., 1993) and was attributed to the initial phase of rifting in the Drava Depression. According to mineral paragenesis, structures and textures, the authors concluded that described trachyandesite represents the part of volcanic succession of the eroded volcanic dome that intruded the basement metamorphic complex and Lower Miocene coarse clastic sediments with tuff intercalations. K-Ar measurements gave the age of trachyandesite between 16 and 15.4 Ma (PAMIĆ et al., 1993).

In this study, two 3D seismic volumes as well as a broad network of 2D seismic reflection profiles were used in the subsurface mapping of the Lower Miocene sedimentary bodies. These sediment successions belong to the Mosti Member, Moslavačka gora Formation, which is a common hydrocarbon-bearing formation in many parts of the Drava Depression. The study is a part of the corresponding author's PhD research which also includes the conclusions about possible hydrocarbon traps. While exploring for stratigraphic and structural traps in order to improve the identification of possible hydrocarbon migration pathways, a part of conducted PhD research included detection of vertical hydrocarbon migration geological features i.e. gas chimneys. Their weak seismic expression is recognized both on 2D and 3D seismic sections as low-amplitude, chaotic, sub vertical features. In a few observed cases gas chimneys are also associated with small-scale folds above them. Gas chimneys were detected throughout Pannonian s.l. sediments, some of them reaching the base of Lake Pannonian clinoforms. Further detailed analyses of reflection seismic profiles revealed a well-preserved volcanic cone with gas chimneys associated to the main volcanic vent and two auxiliary ones.

Petrographic data from well cores of the three deep exploratory wells show that magma firstly intruded the metamorphic basement, then the non-fossiliferous breccia and conglomeratic complex of possible Ottnangian age and was finally capped by Pannonian sediments.

Keywords: *volcanic cone, tectonic activity, Drava Depression*

References

PAMIĆ, J., BELAK, M. & SLOVENEC, D. (1993): Lower Miocene trachyandesites (shoshonites) from Mt. Krndija in Slavonia (Northern Croatia). Rad HAZU, 463, 27-47.

PAVELIĆ, D. (1998): Taložna evolucija slatkovodnog donjeg i srednjeg miocena sjeverne Hrvatske na temelju analize facijesa. Unpubl. PhD Thesis, University of Zagreb, 149 p.

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.

The Storm Wave Deposit at Premantura Rocky Promontory (North Adriatic, Croatia): Origin, Dynamics and Recent Movements

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This study investigates a coastal boulder deposit that was recently identified along the Northern Adriatic coast (Premantura Promontory, Istria, Croatia; BIOLCHI et al., 2019). Accumulations of large boulders have not previously been reported in the North Adriatic Sea, which is a semi-enclosed basin elongated in the SE-NW direction. In particular, we devoted our attention to the mechanisms that may be responsible for the detachment and transport of these large limestone rock fragments, from dm to metric in size, from the emergent part of the coast and from the seabed towards inland areas. For this reason, we adopted a multidisciplinary approach including geological and geomorphological surveys, climate analysis, hydrodynamic modelling together with the use of an Unmanned Aerial Vehicle (UAV). Moreover, ^{14}C AMS datings have been made in order to possibly constrain the age of the detachment of studied boulders.

The deposit is composed of 950 clasts and lies on a low-lying limestone promontory, located in the southernmost tip of Istria, where the topography, the exposure towards the south, together with the bedding planes and dense joint pattern constitute the predisposing factors for boulder size and detachment.

We focused on an isolated boulder characterized by fresh marine carbonate encrustations. Its arrival was reconstructed by means of historical satellite images, wave data and hydrodynamic models and was ascribed to a severe storm which occurred during early 2014. Concerning the remaining boulders, thanks to ^{14}C AMS datings, their deposition can be explained by multiple past extreme wave events.

We explain the boulders detachment as due to frost and salt weathering during severe bora conditions, when air temperatures are below 0°C and waves and associated sea spray fill limestone cracks with water. The freezing and subsequent thawing may cause further ruptures and eventually detachment of limestone fragments. Then, the boulders are carried onshore during major sirocco events when much longer and higher waves are generated. We estimate that sirocco-generated wave heights can exceed ~15 m, which is enough to transport most of observed boulders to their present-day location, according to hydrodynamic equations results. We hypothesize that the boulder detachment mechanism was more effective during the past, when the coastal slope was intact and the boulders were progressively removed and thrown onto the upper storm berm that represents the maximum inundation limit reached by the boulders. Through the centuries, the coast has been eroded through the removal of rocks and has been shaped by truncations of the gently dipping limestone beds that acted as ramps for boulder movements along channels delimited by scarps. The mechanism might have also been favoured over the centuries by slow sea-level rise inundating new portions of the rocky coast, bringing seawater into contact with limestone beds that were previously stable, in a subaerial environment, causing their resizing and rupture.

Figure 1. The isolated boulder emplaced to the coast from the bottom of the sea by extreme waves during 2014. The boulder was recently moved by a strom to the present day position (left, a researcher for the scale), while the ridge of the coastal boulders (right) was emplaced by historical storms at Cape Kamenjak (Premantura, Southern Istria, Croatia).

During the recent 29th October 2018 storm, when sirocco-induced waves reached elevations up to 13 m, ten boulders have been moved. In particular, the isolated boul-

der – emplaced during a severe storm in 2014 – was moved 3 m towards inland with a counterclockwise rotation of 18° (Fig. 1). Boulders that have been interested by movements lie 32 m from the coastaline, about 3 to 4 m a.s.l. These recent movements are evidence of extreme wave power in this sector of the Adriatic Sea that became more frequently affected by exceptional storm events in recent years.

Keywords: *storm wave deposit, coastal boulders, Cape Kamenjak, Adriatic Sea, Croatia*

References

BIOLCHI, S., FURLANI, S., DEVOTO, S., SCICCHITANO, G., KORBAR, T., VILIBIĆ, I. & ŠEPIĆ, J. (2019): The origin and dynamics of coastal boulders in a semi-enclosed shallow basin: A northern Adriatic case study. Marine Geology, 411, 62-77.

Geomorphological Characteristics of the Glaciokarst of the Northern and Central Velebit

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Glaciokarst is a karst area transformed by ice, mainly by the influence of glaciers during the Pleistocene glaciations (VERESS et al., 2019). Velebit Mt. is highly karstified area with lot of different surface and underground karst features. Northern Velebit is known for its numerous, large and deep dolines and especially for the deep vadose zone, where deep caves developed (three are deeper than 1000 m). Due to its complex hydrogeological structure, Central Velebit is characterized by a diversity of surface morphology with numerous ponor zones where large caves have developed. The present research has also shown some preserved geomorphological and sedimentary traces of Pleistocene glaciation on the surface (BOGNAR et al., 1991; BOGNAR & FAIVRE, 2006; VELIĆ et al., 2011; VELIĆ et al., 2017) and in the karst underground (BOČIĆ et al., 2012; BOČIĆ et al., 2013). The aim of this study was to expand knowledge on the geomorphological traces of glaciation, areas of their distribution, and particularly about the mutual influence of the karst and glacial processes on the surface and underground relief. The main methods used were morphometric analysis and geomorphological mapping.

Various denudational e.g. erosional (cirques, glacial valleys, hanging valleys, etc.), depositional (different types of moraines, drumlins, eskers, erratic blocks and moraines-originated debris) and combined glaciokarst forms (dolines-cirques, uvalas-glacial valleys and glaciokarst depressions) on the surface were recorded. Also, cave sediments of glacial or fluvio-glacial origin were recorded. All these morphological traces are difficult to detect due to the modification of subsequent geomorphological processes, especially by karstification. On the other hand, the melting of glaciers (deglaciation of the area) had a positive impact on karst development. This impact is not evenly distributed, so the area is divided into three zones. The central zone includes the highest area of Northern and Central Velebit. Here the drainage of meltwater took place exclusively in the underground through the epikarst and the vadose zone. This has favoured the genesis and development of deep vertical caves. The coast-side zone includes the western slopes dominated by surface drainage of the meltwater. This is how deep gullies in carbonate rocks have been formed. The lower parts of these gullies were subsequently submerged by sea level rise. The inner zone includes the eastern slopes of the research area. It is the most heterogeneous zone and includes the surface and underground drainage of melt water. In this zone, most remnants of cave sediments of the glacial origin have been found.

Keywords: *geomorphology, karst, glaciation, glaciokarst, Velebit*

References

BOČIĆ, N., FAIVRE, S., KOVAČIĆ, M. & HORVATINČIĆ, N. (2012): Cave development under the influence of Pleistocene glaciation in the Dinarides – an example from Štirovača Ice Cave (Velebit Mt., Croatia). Zeitschrift für Geomorphologie, 56/4, 409-433.

BOČIĆ, N., FAIVRE, S., KOVAČIĆ, M. & HORVATINČIĆ, N. (2013): Influence of the Pleistocene glaciations on karst development in the Dinarides – examples from Velebit Mt. (Croatia). Proceedings of 16th International congress of speleology, International Union of Speleology, Brno, 21-29 July 2013, Vol. 3, 170-172.

BOGNAR, A., FAIVRE, S. & PAVELIĆ, J. (1991): Tragovi oledbe na Sjevernom Velebitu [Traces of glaciation in North Velebit – in Croatian, with an English Abstract]. Geografski glasnik, 53, 27-39.
BOGNAR, A. & FAIVRE, S. (2006): Geomorphological Traces of the Younger Pleistocene Glaciation in the Central Part of the Velebit Mt. Hrvatski geografski glasnik, 68(2), 19-30.
VELIĆ, J., VELIĆ, I. & KLJAJO, D. (2011): Sedimentary bodies, forms and occurrences in the Tuderevo and Mirevo glacial deposits of northern Velebit (Croatia). Geologia Croatica, 64(1), 1-16.
VELIĆ, J., VELIĆ, I., KLJAJO, D., PROTRKA, K., ŠKRABIĆ, H. & ŠPOLJAR, Z. (2017): A geological overview of glacial accumulation and erosional occurrences on the Velebit and the Biokovo Mts., Croatia. The Mining-Geology-Petroleum Engineering Bulletin, 32/4, 77-96.
VERESS, M., TELBISZ, T., TÓTH, G., LÓCZY, D., RUBAN, D.A. & GUTAK, J.M. (2019): Glaciokarsts. Springer, Cham, 516 p.

InvestRM – a Multifactor Model for Investment in Raw Material Sector, Case Study Bosnia and Herzegovina

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Under the project InvestRM, multi factor analyses of Bosnia and Herzegovina raw materials, composed of the following elements: (1) Legal data; (2) Social data; (3) Economics data, and (4) Geological data for a total of 120 deposits/geological occurrences of critical raw materials (CRM) existing in B&H – antimony, bauxite, fluorite, magnesite, was conducted. For the purpose of harmonization and standardization of the CRM geological data are aligned with Mineral intelligence network structure and recommendations of the Raw Materials Initiative, making a fundamental contribution to the European Innovation Partnership on Raw Materials (EIP RM).

CRM deposits are described in tables containing following information: basic geological information, deposit characteristics, raw materials characteristics, reserve characteristic, processing characteristic, waste/environmental characteristic and some additional information including supporting literature. Information for each of the deposits have been divided in three categories considering data quality. Data level represents the combination of available references for specific deposit and ability of information to express required characteristics.

Level A: Data are based on references that describe the specific deposit (Technical documentation, Reports, Scientific papers, Geological maps) or references that in details describe the area with similar geological characteristics (for example RAMOVIĆ et al., 1979). Moreover, the benchmark for assessing this level is at least ¾ of essential characteristics delivered in the deposit template.

Level B: Data are based on references that describes the deposit's wider area (Publications, Scientific papers, Geological maps), with similar geological characteristics. The second benchmark for assessing this level is at least ½ of essential characteristics delivered in the deposit template.

Level C: Data are based on references that describes the deposit's wider area on regional scale (Publications, Scientific papers, Geological maps). In this group less than ½ of essential characteristics are delivered in the deposit template.

Data level A and B are obtained for 13 antimony deposits, 42 bauxite deposits, 5 fluorspar deposits and 38 magnesite deposits, while only 22 of the studied deposits have data level C. Geological data, supported with raw materials tailored legal, economic and social data for canton, entity and B&H will be fully accessible via project web page at http/investrm.eu by the end of 2020.

The project is funded by the European Institute of Innovation and Technology (EIT), a body of European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation.

Keywords: *InvestRM on-line tool, critical raw materials, multifactor country analyses, Bosnia and Herzegovina*

References

RAMOVIĆ, M., KUBAT, I., VELJKOVIĆ, D., KULENOVIĆ, E. & ĐURIĆ, S. (1979): Mineral raw materials of Bosnia and Herzegovina, Drugi tom, Knjiga III, Ležišta obojenih metala, Geoinženjering, Sarajevo. Geoengineering Sarajevo, 550 p.

Preliminary Results of Hydrochemical Dynamic of TOC in a Karst Aquifer in the Northern Part of the Dinaric Karst in Croatia

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The term natural organic matter (NOM) refers to a group of organic substances which can be found in surface water and groundwater as a result of natural processes. In a major part NOM is a product of plant degradation and various other biological activities such as metabolic activity of algae, protozoa and microorganisms as well as excretion of fishes and other aquatic organisms (BOLAN et al., 2011). In this paper NOM has been observed as total organic carbon (TOC). Considering that the TOC is mainly contained in the soil zone, from the hydrogeological point of view it might be used as a tracer for infiltration. The behavior of tracer varies considerably between the high and low flow periods (BATIOT et al., 1998). The TOC concentration, chemistry and composition in natural water are highly variable and depend on the sources of organic matter, chemistry of the environment, ionic strength, pH, temperature, major cation composition of the water and on the presence of microbiological and photolytic degradation processes (BOLAN et al., 2011). The determination of TOC concentration in an aqueous solution, such as a sample of wastewater or potable water, is important in different fields including pollution and industrial processing situations.

Measurements were conducted during 17 months, from March 2018 to July 2019 at 9 springs in the northern part of the Dinaric karst in Croatia. The study case encompasses two hypsometric levels of spring and sinking zones of two karst rivers Dobra and Mrežnica. Former studies have shown the complex and heterogeneous karst system of the study area (BIONDIĆ et al.; 1986, BOJANIĆ, 1973; BAHUN, 1968; POLJAK & HERAK 1947, PRELOGOVIĆ et al., 2005). The whole area is significantly disturbed by the tectonic activity. Main structures and faults generally have the typical Dinaric strike (NW-SE), in some cases N-S due to neo-tectonic activity (PRELOGOVIĆ, 2005). The natural hydrogeological dynamic of the aquatic ecosystem were additionally disturbed by the construction of hydrotechnical infrastructure like tunnels, dams and accumulations for hydropower plants. This complex karst system is defined as the boundary zone between deep and shallow karst zone (BOJANIĆ, 1973; KOVAČEVIĆ, 2005). In deep karst zone, groundwater is located on a significant depth with complex and unpredictable flowpaths as a result of intensive karstification. In contrast, carbonate deposits in shallow karst zone are thinner, and impermeable deposits are more common (Tertiary flysch) causing this zone to be rich in surface hydrology with shallow groundwater levels (BAHUN, 1968; KOVAČEVIĆ, 2005).

In order to determine hydrodynamic processes, the following parameters were measured *in situ*: electrical conductivity (EC), pH, oxygen and temperature of spring water on the monthly base. Spring water have been sampled and analysed for cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}), anions (Cl^{-}, SO_4^{2-}, NO_3^{-}) and TOC in hydrochemical laboratory of the Croatian Geological Survey. The scope of this paper is to show the preliminary results and initial relationship between total organic carbon (TOC) and other observed hydrogeological parameters.

Keywords: *karst, TOC, hydrogeology, natural tracers, infiltration*

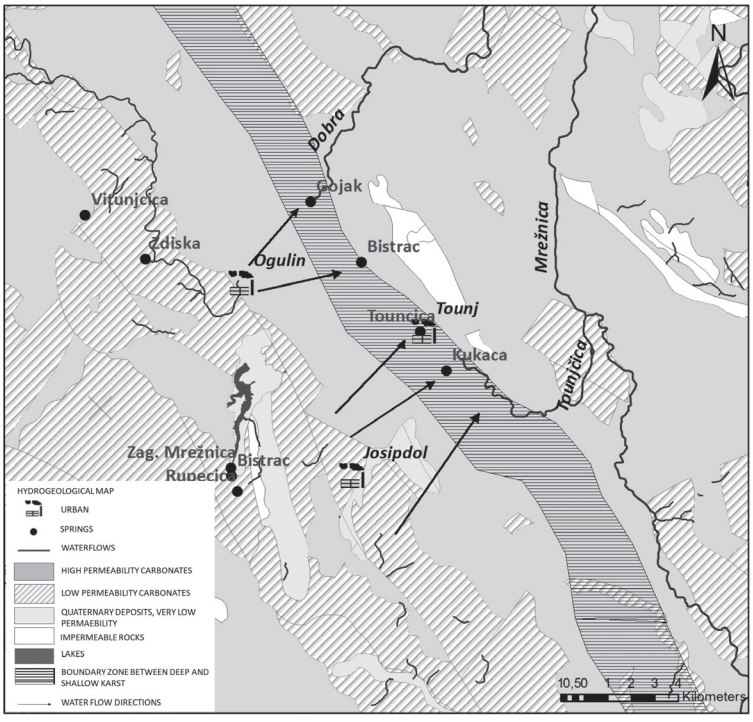

Figure 1. Hydrogeological map of the study area.

References

BAHUN, S. (1968): Geološka osnova hidrogeoloških odnosa krškog područja između Slunja i Vrbovskog. Geološki vjesnik, 12, 19-82.

BATIOT, C.E.C. (2003): Total organic carbon (TOC) and magnesium (Mg2+): two complementary tracers of residence time in karstic systems. CR Geosci, 335(2), 205-214.

BIONDIĆ, B., IVIČIĆ, D., GOATTI, V. & VILJEVAC, Ž. (1986): Hidrogeološka istraživanja u visokom području sliva Zagorske Mrežnice. Prva faza radova. Zagreb: Fond str. dok. Inst. za geol. istraž.

BOJANIĆ, L. (1973): Regionalna hidrogeološka istraživanja područja sliva Kupe. Zagren: Fond str. dok. Inst. za geol. istraživanja.

BOLAN, N., ADRIANO, D., A., K., T.K, J. & MCDOWELL, R. N., S. (2011): Dissolved organic matter: biogeochemistry, dynamics, and environmental significance in soils. (D. L. Sparks, Ed.) Advances in Agronomy, 110, 1-75.

EMBLANCH, C., BLAVOUX, B., PUIG, J.M. & MUDRY, J. (1998): Dissolved organic carbon of infiltration within the autogenic karst hydrosystem. Geophys. Res. Lett., 1459-1462.

KOVAČEVIĆ, A. (2005): Hidrogeološke značajke Karlovačke županije. Zagreb: Faculty of Mining, Geology and Petroleum Engineering.

PRELOGOVIĆ, E., DRAGIČEVIĆ, I., MAJER, D. & BULJAN, R. (2005): Retencija Drežničko polje, Podloge i novelacije idejnog rješenja – geološki i hidrogeološki dio. Zagreb: Fond str. dok. Elektroprojekt.

iTARG3T. Innovative Targeting & Processing of W-Sn-Ta-Li Ores: Towards EU's Self-Supply

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Europe has a large potential for the production and self-supply of tungsten-tin-tantalum-(lithium) (in further text: W, Sn, Ta, and Li) – raw materials 'critical' for the economy. Despite their deposits being abundant, specific problems related to their exploration, resource evaluation, mining, and concentrate production hamper their development. This project aims to overcome these limitations, leading to the opening of new mines by providing innovative tools for deposit targeting & development.

Project iTARGET (duration 2018 – 2021) aims to pave the way for Europe's self-sufficiency in an entire suite of critical raw materials – W, Sn, Ta, Li, and the tools developed will be largely applicable to other mineral deposit types and commodities as well. Europe possesses the metal resources required to make it self-sustainable and to ensure the demand of its industry for many decades. The iTARG3T project aims to contribute significantly to the discovery and development of new W, Sn, Ta, Li deposits in Europe by improving exploration success in environments that are technically challenging and developing mineral processing solutions that will make ores increasingly economic to mine. The combination of exploration with the prediction of geometallurgical behaviour of ores and innovative approaches to obtaining the social license for mining will add value to many existing and new projects and improve the capability of decision makers of going ahead with these projects.

The relationship between felsic peraluminous granitoids and W-Sn-Ta mineralization has been known for a long time but the classical methods using major element geochemistry – with only a few trace elements – are currently superseded by new analytical techniques, isotope geochemistry and highly detailed mineralogy. In brief, mineralizing granites are supposed to be the roots of the vein systems hosted by schists or earlier granitoids or replacement bodies in skarns, but they can host significant mineralization including W(Sn) rich porphyries or sheeted vein systems. The aim of this task is to develop tools for the characterization of granitic units that are the most suitable for being mineralized, either in the exocontact (skarns and veins) or endocontact (sheeted vein systems, disseminations).

The approach for defining these granites includes:

(a) Lithogeochemistry of trace and immobile minor elements such as Ti, Ta, Nb or Zr;

(b) Zircon morphology and trace element geochemistry; and

(c) Sr/Nd isotope geochemistry.

In the area of Bosnia and Herzegovina and Serbia several granite-related W-bearing occurrences exists (Motajica Mt., Prosara Mt., Srebrenica area, Mid-Bosnian Sheets Mts. and Foća-Praća area in Bosnia and Herzegovina, and Bukulja mt., Cer Mt., localities Blagojev Kamen, Cigankulja, Iverak, Osanice, Tanda, Golija Mts. and Kopaonik Mts.

in Serbia; JANKOVIĆ, 1967; RAMOVIĆ et al., 1979) and two are going to be investigated in more details: (1) Motajica Mt., Bosnia and Herzegovina, hosting Paleogene granite cross-cut by pegmatite-albite bodies, greisens and quartz veins including traces of W and Sn with developed alteration zones (JURKOVIĆ, 2004) and (2) Blagojev Kamen, Serbia, hosting chloritic schist of igneous origin and metavolcaniclastic (meta-volcanosedimentary) rock of undetermined age (?Precambrian) with developed granitic and peri-granitic veins and stockworks (greisen): Sn-W, (Cu, Bi, Sb, base metals; JANKOVIĆ, 1982; SCHUMACHER, 1954). Hydrothermal vein system contains scheelite, base-metal sulphides, Au and Cu. Veins are up to 100 m long and 1.2 m thick, containing 1-3.5% WO_3. The area was previously under exploitation.

The project is funded by the European Institute of Innovation and Technology (EIT), a body of European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation.

Keywords: *iTARGET, European Variscan granites, W-Sn-Ta-(Li) deposits, exploration*

References

JANKOVIĆ, S. (1982): Yugoslavia. In: DUNNING, F.W., MYKURA, W. & SLATER, D. (eds): Mineral deposits of Europe, vol. 2: South eastern Europe. The Minerals. Society, IMM, Springer, 143-202.

JURKOVIĆ, I. (2004): Metallogeny of Eocene syncollisional granites of Motajica and Prosara mountins. MGP Bulletin, 16, 31-46.

RAMOVIĆ, M., KUBAT, I., VELJKOVIĆ, D., KULENOVIĆ, E. & ĐURIĆ, S. (1979): Obojeni, plemeniti i rijetki metali. In: ČIČIĆ, S. (ed.): Mineralne sirovine Bosne i Hercegovine *[Mineral raw materials of Bosnia and Herzegovina],* Drugi tom, Knjiga III, Ležišta obojenih metala, Geoinženjering, Sarajevo. Geoengineering Sarajevo, 7-120.

SCHUMACHER, F. (1954): The ore deposits of Yugoslavia and the development of its mining industry. Econ. Geology, 49, 451-492.

Research into Shallow and Deep Geothermal Potential of the Zagreb Area (Croatia)

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Urban areas represent the most important market for geothermal energy. The City of Zagreb is by far the largest urban agglomeration in Croatia with a population exceeding 800,000, and population density higher than 1,232 inhabitants per km^2 (DZS, 2018), with heating season lasting 220 days annually, and a significant potential for both deep and shallow geothermal applications.

Deep geothermal resources are aquifers comprising Badenian bioclastic (*Lithotamnium*) limestones of the Prečec Fm (M) and dolostones, limestones and dolomitic limestones of the Middle and Upper Triassic (T_{2-3}). Boreholes have penetrated the aquifer at depths generally ranging from 800 to 900 m in the central area of the geothermal field, and the water temperatures range from 57 to 85 °C (BOŠNJAK et al., 1998). Zagreb geothermal field had been investigated since 1980-s, but the utilisation level is poor considering the available resource inside densely populated area with existing district heating system. Vintage exploration data are currently being digitalised for the purpose of making a 3D model of the subsurface and thermal model in the scope of Horizon 2020 GeoERA project HotLime.

Although thermal water occurrences are generally a spectacular phenomenon, 85% of the investment into geothermal in the EU is directed toward the shallow subsurface, i.e. heat pump utilisation (EGEC, 2018). Its advantages constitute almost omnipresent potential, lower investment risks and possibility of reversible regime (heating, but also cooling, which has high load in urban surroundings). In the alluvial part of Zagreb urban area it is more favourable to use groundwater heat pumps (GWHPs), while at the foothills of Medvednica Mt. ground source

heat pumps (GSHPs) are successfully installed. Shallow geothermal potential of the area will be investigated in the scope of Horizon 2020 GeoERA project MUSE. The research will concentrate on GWHP applications because the same aquifer is utilised for water supply, and prospects for GSHP installation have been investigated by a previous project GeoMapping (BOROVIĆ et al., 2018, SOLDO et al., 2016).

There exists a competition of multiple users in the shallow subsurface of urban areas (water supply and sewerage systems, geothermal systems, deep underground constructions like hydro-insulated underpasses, underground garages and deep foundations), which can become a conflict issue. That is why existing workflows must be adapted to the needs of local scale urban areas, which will represent the most important SGE market in the future and drive heating and cooling sector decarbonisation.

Both of the mentioned projects have foreseen a wide outreach toward scientific, professional, and general public, as well as toward the regulatory bodies and decision makers, with the final aim to increase the uptake of this readily available resource in the common pilot area, as well as to transfer good practices to other urban areas. That will be achieved through knowledge and experience exchange between sixteen European geological survey organisations which participate in the projects and presented through web sites, GeoERA Information Platform (GIP-P), factsheets, workshops, and congress communications.

Keywords: *thermal water, groundwater heat pump, ground source heat pump, urban area, conflicts in subsurface utilisation*

References

BOROVIĆ, S., URUMOVIĆ, K., TERZIĆ, J. & PAVIČIĆ, I. (2018): Examining thermal conductivities of shallow subsurface materials for ground source heat pump utilization in the Pannonian part of Croatia. The Mining-Geology-Petroleum Engineering Bulletin, 33, 27-35.

BOŠNJAK, R., ČUBRIĆ, S., GOLUB, M., GRABOVSKI, K., JELIĆ, K. et al. (1998): GEOEN – program of geothermal energy utilization, Energy Institute "Hrvoje Požar", Zagreb, 124 p.

CROATIAN BUREAU OF STATISTICS – DZS (2018): Statistical yearbook of the Republic of Croatia, Zagreb, 588 p.

EUROPEAN GEOTHERMAL ENERGY COUNCIL – EGEC (2018): EGEC Annual Report 2018, Brussels, 24 p.

SOLDO, V., BOBAN, L. & BOROVIĆ, S. (2016): Vertical distribution of shallow ground thermal properties in different geological settings in Croatia. Renewable Energy, 99, 1202-1212.

Basic Geological Map of the Republic of Croatia Scale 1:50 000 NP Kornati

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The methodology of the Basic Geological Map of NP Kornati is based on the recognition of the existing and separation of new lithostratigraphic units and the definition of the stratigraphic and structural position of the successions. NP Kornati area (small central part of the former Mesozoic Adriatic Carbonate Platform) is 217 km^2 of which land surface (89 islands) makes 50 km^2. Field geological mapping of NP Kornati has resulted with data of deposits distribution, tectonic deformations and structural-tectonic relationships. Map production implies preparation of the existing documentation, prospection, defining and sampling of stratigraphic sections/profiles, geological mapping and reambulation, cabinet and laboratory research (KORBAR et al., 2012).

Project team of CGS, with the financial and logistical support of the NP Kornati (03/2018-03/2019) performed the predefined activities: geological mapping, defining and sampling of stratigraphic sections/profiles, structural-tectonic research, sampling of selected speleological objects, field input and graphical data display, reambulation, production of geological map in printed form, creating vector and raster files. Map contains 12 lithostratigraphic units with stratigraphic range from lower Cenomanian to Holocene, 10 formations (Belej, Milna, Sv. Duh, Basina, Gornji Humac, Foraminiferal limestone, Terra rossa, Brown soil, Rock creep and Storm blocks) and 2 members (Baldarin and Gračišće). Belej formation (lower-middle Cenomanian) deposits are presented with medium to thick-layered pelagic limestones with calcisphere and planktonic foraminifera. Milna formation (lower-upper Cenomanian) are dominantly presented by shallow-marine mud and grainy limestones (with a periodic appearance of *Chondro-*

donta coquina), concordantly follows by Sv. Duh formation (upper Cenomanian-lower Turonian) with thick-layered pelagic (calcisphere and planktonic foraminifera) limestones. Gornji Humac formation (Turonian-Campanian) is composed mainly from peritidal limestones with numerous benthic foraminifera, *Taumathoporella*, *Decastronema* and rudists (*Radiolitidae*, *Hippuritidae*). In the central and south-eastern limited area of the NP Kornati, Foraminiferal limestones (lower-middle Eocene) disconcordantly overlaying on GH formation. The characteristics of these deposits are thick-layered limestones with abundance of large benthic foraminifera (*Alveolina*, *Nummulites*, miliolidae). Locally isolated occurrences of Terra rossa, Brown soil, Rock creep and Storm blocks are also shown on the map. Generally, Dinaridic NW-SE thrusting (Paleogene-Neogene) and N-S (Pliocene-Quaternary) tectonics marks the tectonic map of the Kornati area. Other objectives of cooperation on BGM of the NP Kornati were better preventive protection of the area, geological processing 42 speleological objects, enrichment of visitor centre content, education about the value of NP area, help in branding the area, and publication of scientific and popular-scientific papers in journals.

Keywords: *NP Kornati, Geological Map, limestones, Adriatic Carbonate Platform*

References

KORBAR, T., AVANIĆ, R., BAKRAČ, K., BELAK, M., BERGANT, S., BRČIĆ, V., BRLEK, M., FUČEK, L., GRGASOVIĆ, T. GRIZELJ, A., HALAMIĆ, J., HEĆIMOVIĆ, I., HORVAT, M., JAMIČIĆ, D., KOCH, G., MATIČEC, D., OŠTRIĆ, N., PALENIK, D., SLOVENEC, D. & ŠORŠA, A. (2012): Guidelines for compilation of the Basic geological map of the Republic of Croatia: scale 1:50.000, 132 p.

Geochemical and Mineralogical Evidences for Possible Bog Iron Formation in Podravina Region, NE Croatia

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Bog iron ores are sedimentary types of iron deposits (RAMANAIDOU & WELLS, 2014), typically occurring in low-lying areas such as swamps, bogs and meadows or river valleys and microdepressions with a groundwater table situated close to the surface (KACZOREK & ZAGÓRSKI, 2007). They represent terrestrial accumulations of Fe ore in the form of various Fe oxides and oxyhyroxides, such as goethite (BANNING, 2008) and are often developed in hydromorphic, loamy, sandy and clayey alluvium and soil (DE GEYTER et al., 1985, LANDUYDT, 1990). During several decades of archaeological investigations throughout the Podravina region, numerous sights of iron smelting workshops, furnaces and iron slag materials were found (VALENT et al., 2017). Archaeological evidences indicate presence of near-by bog iron excavation sites (SEKELJ IVANČAN, 2017). The aim of this study is to present evidences for possible bog iron ore formation in the wider area of the Drava River valley, Podravina region, NE Croatia. Based on high amounts of archaeological evidences and findings pointing toward the usage of bog iron ore in Podravina region, detailed geological exploration was conducted in the area. A total of 44 soil profiles were drilled, most of them in the vicinity of previously established archaeological locations. Six soil profiles, consisting of five Gleysols and one Fluvisol were selected for further mineralogical, geochemical and textural analyses due to visible iron accumulations throughout their depth.

The X-ray diffraction (XRD) analyses confirmed goethite, quartz, clay minerals, plagioclase, feldspars, and sporadically dolomite. Chemical analyses indicate variable, but high concentrations of iron oxide in all profiles, generally higher than median values for Podravina region (HALAMIĆ & MIKO, 2009). Kalinovac-Hrastova Greda profile shows highest concentration of Fe_2O_3 (31.52%) at 60–80 cm depth, while remaining profiles show Fe_2O_3 concentrations between 3.97–10.90%. Concentrations of As (1.8–563.6 ppm) and P (484–4513 ppm) show high enrichment values of these elements in the selected soils. Textural analyses indicate high amount of silt and sporadically sand in all profiles, with relatively small amounts of clay. Enrichment factor of Fe_2O_3 shows significant enrichment in Kalinovac-Hrastova Greda profile, indicating possible ore formation. Based on microelement distribution of Ce, Cs, Hf, La, P and Zr, all soils show a common parent material, but significant differences in concentrations of Fe and other major oxides indicate

different formation processes. This is attributed to differences in soil texture of selected soil profiles, oscillations of groundwater table (BRKIĆ & BRIŠKI, 2018), and changes of oxidative and reductive conditions. The results of this study indicate that Podravina region is a suitable area for the formation of bog iron ore, although recent conditions inhibit formations of bog iron ore due to changes in agriculture and melioration which are altering groundwater levels.

Keywords: *bog iron ore, pedology, geoarchaeology, Podravina region, geochemistry*

References

BANNING, A. (2008): Bog Iron Ores and their Potential Role in Arsenic Dynamics: An Overview and a „Paleo Example". Engineering in Life Science, 8/6, 641-649.

BRKIĆ, Ž. & BRIŠKI, M. (2018): Hydrogeology of the western part of the Drava Basin in Croatia. Journal of Maps, 14(2), 173-177.

DE GEYTER, G., VANDENGERGHE, R.E., VERDONCK, L. & STOOPS, G. (1985): Mineralogy of holocene bog-iron ore in northern Belgium. Neus Jahrbuch fuer Mineralogie Abhandlungen, 153, 1-17.

KACZOREK, D. & ZAGÓRSKI, Z. (2007): Micromorphological characteristics of the bsm horizon in soils with bog iron ore. Polish Journal of Soil Science, 40, 81-87.

RAMANAIDOU, E. & WELLS, M.A. (2014): Sedimentary Hosted Iron Ores. Treatise on Geochemistry, 13, 313-355.

SEKELJ IVANČAN, T. & MARKOVIĆ, T. (2017): The primary processing of iron in the Drava River basin during the late Antiquity and the early Middle Ages – the source of raw materials. Archaeological Studies: Raw material exploitation from prehistory to the Middle Ages, 143-161. Belgrade, Serbia.

VALENT, I., ZVIJERAC, I. & SEKELJ IVANČAN, T. (2017): Topografija arheoloških lokaliteta s talioničkom djelatnošću na prostoru Podravine [*eng.* Topography of Archaeological localities with smelting plants in the area of Podravina]. Podravina, 16(32), 5-25.

Geology-Themed Museum Publications as a Platform for Popularization of Geology and Geological Heritage

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The mission of a museum is, among other things, to educate a wide range of audience about the field of its expertise. The museum communicates with visitors through exhibitions but also through a medium of museum publications. Publications serve to transmit and distribute professional and scientific knowledge to museum visitors. Museums task is to promote geological heritage. The inclusion of geological and geomorphological heritage in tourist offerings becomes increasingly important (MIKHAILENKO & RUBAN, 2019). Many museums use marketing ideas to reach their visitors needs (BULJUBAŠIĆ & JURIĆ, 2016).

Geology-themed museum publications are aimed at presenting some of the most important or popular sites of geological heritage throughout Croatia, represented by the geological findings stored in the holdings of the museum collections. This gives them influence in the promotion of geology and geological heritage sites. Thus, museums with their activities, together with the geological heritage *in situ*, form a whole, significant for the popularization of geology, geological sites, but also for strengthening the implementation of the active protection of geological heritage on regional, national and international levels. A few museums have a continuous production of geological publications: Croatian Natural History Museum, Krapina Neanderthal Museum, Natural History Museum Split and Natural History Museum Rijeka. Some of the city and county museums occasionally publish publications of geological themes in cases if they have a geological or paleontological collection in the museum, if there is a geological or paleontological site in their vicinity that museum wants to promote, or to create it as a *brand*, or in case if they host guest exhibition (ZWICKER et al. 2008). Geologically-themed publications are also considered according to target groups, their interest or age (RADOVANLIJA MILEUSNIĆ, 2013). Some of them are aimed for the experts but the majority are for beginners and geology amateurs (KIERSTEN & SIMMONS, 2014). The role of those publications is to inform, educate on geological terms, geological sites, events that happened in certain geological periods, but also on some significant and especially important geologists. Also, they should encourage curiosity or open the way to some further, more

thorough professional expertise. Geology can be learned from early ages through colouring and picture books which can be their first encounter with geology, fossils or minerals. The very widespread type of publications are guides, rather interesting reading material, also useful for use in nature while walking or hiking, due to their contents that can help in identification when looking for a fossil, mineral, rock or some geological phenomenon (HOSE, 2016).

Recently, visitors show a growing interest for the so-called non-book material (but still considered as publication). A bookmark illustrated with geological periods turned to be a favourite among students and adults, precisely because it gives useful, short info about geological periods (names, years, type of life). A poster of an interesting geological phenomenon, or, for example, a poster presentation of a mineral or fossil collection, has not only an aesthetic function in public or private space but at the same time, it informs about the existence of such geological phenomenon or collection. Such motifs promote, as well as »invite« people to visit the museum or the locality. Some of the non-book publications we consider as souvenirs but they also have an educational purpose and serve to popularize geology. A postcard of a geological site or fossils or minerals with a mapped location may inspire curiosity and encourage the recipient to visit the site. The cup with printed motifs of the geological alphabet, besides its primary use, has an educational function by promoting geological terms so they can become more familiar to the user. Primary and secundary shool children make the majority of museum visitors. Museum are not schools so the learning must be different, informal (MAROEVIĆ, 1990). We are aware of insufficient teaching about geology in our schools so geological museum publications are an excellent complementary tool to the inadequate school curriculum. Those publications are useful both to the teachers and students as auxiliary school supplements, also helpful in planning of school (and family) excursions because they can serve as guides at a specific location. Museum have an important role in geoturism (JAKUBOWSKI, 2004). The popularization of geology through such museum publications has an increasingly important role in geotourism.

The goal of producing geologically themed publications, with above mentioned, is certainly national and international promotion of the Croatian geological heritage. The Museum with its promotional activities and the presentation of geological publications, and participation in scientific and cultural manifestations promotes and stimulates public interest for geology. Purchasing geological-themed museum publications is a good indicator of interest for geology, and for geological heritage as well.

Keywords: museum, publications, geology, geological heritage

Figure 1. Selection of geologicaly-themed publications of Croatian Natural History Museum.

References

BULJUBAŠIĆ, I. & JURIĆ, I. (2016): Potencijali marketinga u gradskim muzejima (Marketing potentials in town museums), Sociokulturno nasljeđe i gospodarski razvoj / Šundalić, Antun ; Zmaić, Krunoslav ; Sudarić, Tihana ; Pavić, Željko – Osijek : Studio HS, 141-156.

HOSE, T.A. (2016): Geoheritage and geoturism – A European perspective, The International Centre For Culture and Heritage Studies, Newcastle University.

KIERSTEN, F.L & SIMMONS, E.J. (2014): Foundations of museum Studies – Evolving systems of knowledge, Librarires Unlimited, St. barbara, Cal. USA.

MAROEVIĆ, I. (1990): Promjene u muzejima i promjene za obrazovanjem, Informatica Museologica 1/2, Muzejski dokumentacijski centar, Zagreb, 89-90.

MIKHAILENKO, A. & RUBAN, D.A. (2019). Heritage Specific Visibility as an Important Parameter in Geo-Tourism Resource Evaluation, Geosciences, 9(4), Basel, p. 146.

RADOVANLIJA MILEUSNIĆ, S. (2013): How to publish a good museum book – educational workshops about museum publishing, Informatica museologica, Vol. 44 No., Museum Documentation Center, p. 1-4.

ZWICKER, G., ŽEGER PLEŠE, I. & ZUPAN, I. (2008): Zaštićena geobaština Republike Hrvatske, Državni zavod za zaštitu prirode, Zagreb.

Excess Air in Spring Water as Indicator of "Open" or "Closed" Flow in Karst System

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Environmental tracers in ground water are naturally present substances and physical properties of the water that are depended on flow properties and processes happening within the groundwater flow system. Monitoring of such tracers in karst spring water enables insight in characteristics of typically extremely heterogeneous and complex karst groundwater systems. Commonly used environmental tracers include electrical conductivity, temperature, turbidity, ionic composition, stable isotopes of water, organic carbon, nitrates, etc. These tracers provide valuable information regarding infiltration mechanisms, epikarst function, mean groundwater transit times, dynamics of fast and slow flow, etc (TRČEK & ZOJER, 2010). Air saturation in spring water is not commonly monitored parameter in hydrogeological studies, although supersaturation with air, or "excess air", is a phenomenon which periodically or permanently occurs on some karstic springs (SURBECK, 2005; HEATON & VOGEL, 1981). On the other hand it is a very important parameter for fish farming, as oversaturation with gases can cause fatal "gas bubble disease" in fish (MACHOVA et al., 2017; WEITKAMP & KATZ, 1980). Therefore, fish farming community is well aware of this phenomenon. Krbavica spring, situated near Krbavsko polje in Croatian Lika region, is known among local population as inadequate for fish farming although it is a permanent spring with a relatively stable discharge even in draught periods. Bubble formation is visible in a spring pool during the most of the year.

The spring is captured for public water supply, and monitoring program on it was established to investigate properties of the karst system which feeds it. Among other natural tracers, dissolved oxygen, as an indicator of "excess air" in spring water, was also monitored in high temporal resolution. Monitoring data shows that oxygen saturation is in clear relation to discharge dynamics. During peaks in hydrograph values of oxygen saturation temporarily dropped, followed by maximum values with delay of several days. Increased oxygen saturation was interpreted as an increased proportion of flow through narrow fractures in a vadose zone in a closed flow conditions. Air bubbles captured in water infiltrating to narrow fractures gradually dissolve due to pressure rising and isolation from the atmosphere. In contrary, water flow through larger, karstified fractures and conduits in vadose zone is in open flow conditions, i.e. water pressure is equilibrated with the atmospheric pressure. Therefore, drops in oxygen oversaturation during hydrograph peaks are interpreted as a consequence of increased flow through larger openings within the vadose zone. Flow through narrower fractures is most intense after the rainfall events, when pressure rising in fractures mobilises water. In order for groundwater to remain oversaturated, conduits within the deeper parts of the system that drain water to the spring should be dominantly phreatic, i.e. situated completely below the groundwater level. It can be concluded that monitoring of air saturation in spring water can provide valuable information on the processes within the system, especially if it is combined with monitoring of discharge dynamics and additional tracers.

Keywords: *Karst hydrogeology, environmental tracer, "excess air", Krbavica spring*

References

HEATON, T.H.E. & VOGEL, J.C. (1981): "Excess air" in groundwater. Journal of Hydrology, 50, 201-216.

MACHOVA, J., FAINA, R., RANDAK, T., VALENTOVA, O., STEINBACH, C., KOCOUR KROUPOVA, H. & SVOBODOVA, Z. (2017): Fish death caused by gas bubble disease: a case report. Veterinarni Medicina, 62, 231-237.

SURBECK, H. (2005): Dissolved gases as natural tracers in karst hydrogeology; radon and beyond. Center of Hydrogeology (CHYN), University of Neuchâtel, Emile-Argand, 11, 23 p.

TRČEK, B. & ZOJER, H. (2010): Recharge of springs. In: KREŠIĆ, N. & STEVANOVIĆ, Z. (eds.): Groundwater hydrology of springs: engineering, theory, management, and sustainability. Butterworth – Heinemann, 87-127.

WEITKAMP, D.E. & KATZ, M. (1980): A Review of Dissolved Gas Supersaturation Literature. Transactions of the American Fisheries Society, 109 (6), 659-702.

Groundwater Age Dating as a Tool for Nitrogene Pollution Risk Assessment in Croatia

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Groundwater is a valuable natural resource and has to be protected from any chemical pollution. The most common source of groundwater contamination is intensive agricultural activity and, as its consequence, an increased nitrate concentration in groundwater. Agricultural activity is most intensively represented in lowland areas where the most productive aquifers are often located. In these aquifers, groundwater has relatively long travel time of pollutants from the ground surface to the observation borehole. Using groundwater dating, the measured concentrations of pollutants can be directly related to the time of recharge (BROERS, 2004; MORGENSTERN et al., 2015; VISSER, 2009). In that sense, the question arises can we detect trends and trend reversal in groundwater quality using groundwater age? Studies have shown that this is possible (HANSEN et al., 2012, 2017; VISSER, 2009).

Groundwater quality in Croatia is generally relatively good. Mean nitrate concentrations in groundwater are mostly below 15 mg/L, while in the southern, karst areas, they rarely exceed 5 mg/L. However, in the western (Istria peninsula) and north-western parts of Croatia, concentrations of nitrates in the groundwater may exceed the threshold values (BIONDIĆ et al., 2016; NAKIĆ et al., 2016). As a result, in the Water Management Plan for 2016–2021 (HRVATSKE VODE, 2016) groundwater bodies (GWBs) in these areas are declared as GWBs of poor chemical status and are at risk of failure to achieve the goal of "preventing status deterioration".

Dating of groundwater age using environmental tracers in these areas started two years ago and the research is still ongoing. The aim of this research is to develop and improve tools to detect trends of nitrates in groundwater in Croatia. Groundwater samples were collected at 10 locations. Environmental tracers, as CFCs (chlorofluorocarbons), SF_6 (sulphur hexafluoride), ^3H (tritium) and ^3He (helium-3) were measured. Their content in the groundwater was compared with historical data on their content in the air based on which the mean groundwater age was assessed. The estimated mean groundwater age was analysed in relation to the pressures from the agricultural activity. The research points out interesting results that can contribute to a better assessment of the future nitrate trends in the investigated areas.

Keywords: environmental tracer, mean residence time, groundwater age distribution, nitrates, trend

References

BIONDIĆ, R., RUBINIĆ, J., BIONDIĆ, B., MEAŠKI, H. & RADIŠIĆ, M. (2016): Definiranje trendova i ocjena stanja podzemnih voda na području krša u Hrvatskoj [Definition of trends and groundwater status assessment in the karst part of the Croatia – in Croatian]. Geotechnical faculty, University of Zagreb.

BROERS, H.P. (2004): The spatial distribution of groundwater age for different geohydrological situations in the Netherlands: implications for groundwater quality monitoring at the regional scale. Journal of hydrology, 299, 85-106.

HANSEN, B., DALGAARD, T., THORLING, L., SORENSEN, B. & ERLANDSEN, M. (2012): Regional analysis of groundwater nitrate concentrations and trends in Denmark in regard to agricultural influence. Biogeosciences, 9, 3277-3286.

HANSEN, B., THORLING, L., SCHULLEHNER, J., TERMANSEN, M. & DALGAARD, T. (2017): Groundwater nitrate response to sustainable nitrogen management. Scientific Reports, 7:8566. DOI: 10.1038/s41598-017-07147-2

HRVATSKE VODE (2016): Plan upravljanja vodnim područjima 2016.-2021. [River Basin Management Plan for 2016-2021 – in Croatian]. Hrvatske vode, Zagreb, Croatia.

MORGENSTERN, U., DAUGHNEY, C.J., LEONARD, G., GORDON, D., DONATH, F.M. & REEVES, R. (2015): Using groundwater age and hydrochemistry to understand sources and dynamics of nutrient contamination throug the catchement into Lake Rotorua, New Zeland, Hydrology and Earth System Sciences, 19, 803-822.

NAKIĆ, Z., BAČANI, A., PARLOV, J., DUIĆ, Ž., PERKOVIĆ, D., KOVAČ, Z., TUMARA, D., MIJATOVIĆ, I., ŠPOLJARIĆ, D., UGRINA, I. et al. Definiranje trendova i ocjena stanja podzemnih voda na području panonskog dijela Hrvatske [Definition of trends and groundwater status assessment in the Pannonian part of the Croatia – in Croatian]. Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb.

VISSER, A. (2009): Trends in groundwater quality in relation to groundwater age, PhD thesis, Netherlands Geographical Studies 384, Faculty of Geosciences, Utrecht University, Netherlands.

Miocene Syn-Rift Evolution of the North Croatian Basin (Carpathian-Pannonian Region): 1. Regional Magmatic Activity and Mts. Kalnik and Požeška Gora Pyroclastic Record

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Pannonian Basin, being part of the Carpathian-Pannonian Region (CPR, Alpine–Carpathian–Dinaridic orogenic system; HANDY et al., 2014), represents a "back-arc" basin formed due to Oligocene–Miocene subduction roll-back in the Carpathians and Dinarides (HORVÁTH et al., 2015; BALÁZS et al., 2016; van GELDER, 2017). Valuable information concerning the North Croatian Basin (NCB; PAVELIĆ & KOVAČIĆ, 2018) syn-rift evolution, interpreted to have developed due to Early–Middle Miocene extension in the SW margin of the Pannonian Basin, are archived in Mts. Kalnik and Požeška gora Lower–Middle Miocene pyroclastic and sedimentary rocks. However, no state-of-the-art multi-proxy approach has been applied so far on the most promising localities (Croatian Geological Survey data) in order to resolve many crucial local and regional open questions and refine currently available reconstructions.

Complex post-collisional (SEGHEDI & DOWNES, 2011) tectonic processes (e.g., core-complex and wide-rift types of extension) in the CPR generated, together with evolution of magmas in the crustal environment, Lower Miocene to Recent magmatic rocks of highly diverse composition. Magmatic activity shows a distinct migration in time from west to east (PÉCSKAY et al., 2006; SEGHEDI & DOWNES, 2011). The most complex and abundant group of CPR magmatic rocks is the calc-alkaline group (SEGHEDI & DOWNES, 2011; LUKÁCS et al., 2018). LUKÁCS et al. (2018) constrained the lasting (as well as petrogenesis and geodynamic setting) of large silicic volcanic activity recorded as Bükalja Volcanic Field (BVF, Hungary) silicic pyroclastics from 18.2 to 14.4 Ma. Calc-alkaline magmatic activity (20–16 Ma) associated with core-complex formation related to Pannonian Basin extension is recorded in the Vardar Zone (Internal Dinarides; SEGHEDI & DOWNES, 2011; SCHEFER et al., 2011; ANDRIĆ et al., 2018). Early–Middle Miocene volcanic activity was also recorded in the NCB in the form of volcanics and pyroclastics occurring intercalated with penecontemporaneous alluvial, lacustrine and marine sediments (PAMIĆ et al., 1995; PAMIĆ, 1997; PAMIĆ & BALEN, 2001a, b; MANDIĆ et al., 2012; MARKOVIĆ, 2017).

Mt. Kalnik pyroclastics were dated (Ar/Ar) at 18.07 ± 0.07 Ma (Early Miocene, ~ Eggenburgian/Ottnangian transition) by MANDIĆ et al. (2012), constraining the timing of the initial rifting tectonics of the NCB (since they occur intercalated with alluvial sediments representing the base of NCB continental series). TIBLJAŠ et al. (2002) and MANDIĆ et al. (2012) correlated Mt. Kalnik pyroclastics with Upper Oligocene–Lower Miocene (Egerian–Eggenburgian) andesites and dacites, as well as pyroclastics, outcropping in north Croatia (Hrvatsko Zagorje Basin-HZB, AVANIĆ, 2012). HZB volcanic rocks are interpreted to be

related to the easternmost part of the Periadriatic Fault Zone (PFZ) and/or slab breakoff magmatic activity (PALINKAŠ & PAMIĆ, 2001; PAMIĆ & BALEN, 2001a, b). However, Periadriatic (PFZ) magmatic rocks *sensu stricto* of the Alps (as well as magmatic belt within the Western Carpathians north of the Mid Hungarian fault Zone), are represented by Paleogene (mostly Oligocene) plutons with age span of 28–42 Ma (ROSENBERG, 2004; NEUBAUER et al., 2018). Geodynamic setting and formation processes of the eastern younger magmatic (intrusive and volcanic) and pyroclastic rocks, ranging from ~ 20–14 Ma and located north and south of PFZ, is unresolved (e.g., Mt. Pohorje magmatism; FODOR et al., 2008; NEUBAUER et al., 2018).

The most reliable age determination of Middle Miocene (Badenian) pyroclastics intercalated with NCB lacustrine and marine deposits is provided by MANDIĆ et al. (2012) and MARKOVIĆ (2017). This age determination is based on high-precision Ar/Ar dating of sanidine. Age span of intermediate to acid pyroclastics provided by these authors, occurring in several NCB localities, is 16.03–14.40 Ma. Mt. Papuk Nježić locality (14.40 ± 0.03 Ma) and Mt. Medvednica Čučerje locality (14.81 ± 0.08 Ma) have been related (LUKÁCS et al., 2018) to CPR BVF Harsány and Demjén ignimbrites, respectively.

In order to make reliable tephrochronological and volcanic provenance (as well as petrogenetic and geodynamic setting) reconstructions of Mts. Kalnik and Požeška gora (intercalated with Lower–Middle Miocene marine deposits) pyroclastics, state-of-the-art volcanological, petrological, high-precision geochronological (EARTHTIME initiative), geochemical and isotopic analysis are being conducted. Such high-resolution data will also provide an absolute age constraint of NCB syn-rift evolution and biostratigraphy, as well as add valuable new data for more comprehensive understanding of the regional (i.e., CPR-related) magmatic and geodynamic evolution (and their mutual relationship).

Keywords: *Miocene, North Croatian Basin, syn-rift, volcanism, Carpathian-Pannonian Region*

References

ANDRIĆ, N., VOGT, K., MATENCO, L., CVETKOVIĆ, V., CLOETHING, S. & GERYA, T. (2018): Variability of orogenic magmatism during Mediterranean-style continental collisions: A numerical modelling approach. Gondwana Research, 56, 119-134.

AVANIĆ, R. (2012): Litostratigrafske jedinice donjeg miocena sjeverozapadne Hrvatske [Lower Miocene lithostratigraphic units from north-western Croatia – in Croatian, with an English Abstract]. Unpubl. PhD Thesis, Faculty of Science, University of Zagreb, 162 p.

BALÁZS, A., MATENCO, L., MAGYAR, I., HORVÁTH, F. & CLOETHING, 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.

FODOR, L.I., GERDES, A., DUNKL, I., KOROKNAI, B., PÉCSKAY, Z., TRAJANOVA, M., HORVÁTH, P., VRABEC, M., JELEN, B. & FRISCH, W. (2008): Miocene emplacement and rapid cooling of the Pohorje pluton at the Alpine-Pannonian-Dinaridic junction, Slovenia. Swiss Journal of Geosciences, 101, 255-271.

HANDY, M.R., USTASZEWSKI, K. & KISSLING, E. (2014): Reconstructing the Alps–Carpathians–Dinarides as a key to understanding switches in subduction polarity, slab gaps and surface motion. International Journal of Earth Sciences, 104, 1-26.

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.

LUKÁCS, R., HARANGI, GUILLONG, M., BACHMANN, O., FODOR, L., BURET, Y., DUNKL, I., SLIWINSKI, J., von QUADT, A., PEYTCHEVA, I. & ZIMMERER, M. (2018): Early to Mid-Miocene syn-extensional massive silicic volcanism in the Pannonian Basin (East-Central Europe): Eruption chronology, correlation potential and geodynamic implications. Earth-Science Reviews, 179, 1-19.

MANDIĆ, 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.

MARKOVIĆ, F. (2017): Miocenski tufovi Sjevernohrvatskoga bazena [Miocene tuffs from North Croatian Basin – in Croatian, with an English Abstract]. Unpubl. PhD Thesis, Faculty of Science, University of Zagreb, 174 p.

NEUBAUER, F., HEBERER, B., DUNKL, I., XIAOMING, L., BERNROIDER, M. & DONG, Y. (2018): The Oligocene Reifnitz tonalite (Austria) and its host rocks: Implications for Cretaceous and Oligocene-Neogene tectonics of the south-eastern Eastern Alps. Geologica Carpathica, 69, 237-253.

PALINKAŠ, L.A. & PAMIĆ, J. (2001): Geochemical evolution of Oligocene and Miocene magmatism across the Easternmost Periadriatic Lineament. Acta Volcanologica, 13, 41-56.

PAMIĆ, J. (1997): Volcanic rocks of the Sava–Drava interfluve and Baranja in Croatia. Monograph, Nafta, Zagreb, 192 p. (in Croatian).

PAMIĆ, J. & BALEN, D. (2001a): Tertiary magmatism of the Dinarides and the adjoining South Pannonian Basin: an overview. Acta Vulcanologica, 13, 9-24.

PAMIĆ, J. & BALEN, D. (2001b): Petrology and geochemistry of Egerian-Eggenburgian and Badenian tholeiite-calcalkaline volcanics from the South Pannonian Basin (Croatia). Neues Jahrbuch für Mineralogie – Abhandlungen, 176, 237-267.

PAMIĆ, J., MCKEE, E.H., BULLEN, T.D. & LANPHERE, M.A. (1995): Tertiary Volcanic Rocks from the Southern Pannonian Basin, Croatia. International Geology Review, 37, 259-283.

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.

PÉCSKAY, Z., LEXA, J., SZAKÁCS, A., SEGHEDI, I., BALOGH, K., KONEČNÝ, V., ZELENKA, T., KOVACS, M., PÓKA, T., FÜLÖP, A., MÁRTON, E., PANAIOTU, C. & CVETKOVIĆ, V. (2006): Geochronology of Neogene magmatism in the Carpathian arc and intra-Carpathian area. Geologica Carpathica, 57, 511-530.

ROSENBERG, C.L. (2004): Shear zones and magma ascent: A model based on a review of the Tertiary magmatism in the Alps. Tectonics, 23, TC3002. doi: 10.1029/2003TC001526.

SCHEFER, S., CVETKOVIĆ, V., FÜGENSCHUH, B., KOUNOV, A., OVTCHAROVA, M., SCHALTEGGER, U. & SCHMID, S.M. (2011): Cenozoic granitoids in the Dinarides of southern Serbia: age of intrusion, isotope geochemistry, exhumation history and significance for the geodynamic evolution of the Balkan Peninsula. International Journal of Earth Sciences, 100, 1181-1206.

SEGHEDI, I. & DOWNES, H. (2011): Geochemistry and tectonic development of Cenozoic magmatism in the Carpathian-Pannonian region. Gondwana Research, 20, 655-672.

TIBLJAŠ, D., LOPARIĆ, V. & BELAK, M. (2002): Discriminant function analysis of Miocene volcaniclastic rocks from north-western Croatia based on geochemical data. Geologia Croatica, 55, 39-44.

van GELDER, I. E. (2017): Interfering orogenic processes derived from Alps-Adria interactions. Dissertation, Utrecht Studies in Earth Sciences, 125, 169 p.

Miocene Syn-Rift Evolution of the North Croatian Basin (Carpathian-Pannonian Region): 2. Initial Central Paratethys Flooding and Mt. Požeška Gora Case Record

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The spatial and temporal evolution of the Paratethys Sea during the Early to Middle Miocene, as well as the chronologic framework to disentangle geodynamic and climatic processes affecting the depositional environments, is still not resolved (HILGEN et al., 2012; de LEEUW et al., 2018; SANT et al., 2017; KOVÁČ et al., 2018). Covering almost the entire area of northern Croatia and situated southeast of the Hrvatsko Zagorje Basin (HZB; AVANIĆ, 2012), North Croatian Basin (NCB; PAVELIĆ & KOVAČIĆ, 2018) evolved during the Early Miocene, and belongs geo-tectonically to the south-western margin of the Pannonian Basin (PB, part of Carpathian-Pannonian Region, CPR; HORVÁTH et al., 2015; BALÁZS et al., 2016). Typical syn-rift sedimentary successions of the initial basal Lower-Middle Miocene (Ottnangian-Lower Badenian according to PAVELIĆ & KOVAČIĆ, 2018 and references therein) NCB comprise continental, alluvial and lacustrine (Southern Pannonian Basin Lake System, SPBLS *sensu* MANDIC et al., 2019a) sediments unconformably overlying a strongly tectonized basement. According to ĆORIĆ et al. (2009), MANDIC et al. (2012, 2019a, 2019b), MARKOVIĆ (2017) and PAVELIĆ & KOVAČIĆ (2018 and references therein), initial Miocene marine flooding of the NCB corresponds to the main Badenian (Middle Miocene) transgressive pulse of Central Paratethys, that is Middle Badenian (NN5 Zone, TB 2.4 after HOHENEGGER et al., 2014). These recent studies are based on radiometric dating ($^{40}Ar/^{39}Ar$ dating) of the pyroclastic horizons (intercalated with alluvial, lacustrine and marine NCB deposits; MANDIC et al., 2012; MARKOVIĆ, 2017) and integrated biostratigraphy, which constrained the age of Lower-Middle Miocene NCB deposits analyzed therein (e.g., Mts. Medvednica and Papuk localities).

However, according to BRLEK et al. (2018), the exact timing of the initial Early-Middle Miocene flooding of different parts of NCB, necessary for reconstructing Early-Middle Miocene stratigraphic evolution of the NCB (e.g., PAVELIĆ & KOVAČIĆ, 2018), is still unresolved due to:

1/ sparse and uncomprehensive integrated calcareous plankton biostratigraphic determinations of Lower-Middle Miocene NCB marine sediments which are insufficiently calibrated (together with lacustrine sediments) with high-precision geochronological

studies (especially necessary in semi-enclosed Paratethys Sea; HILGEN et al., 2012; SANT et al., 2017; KOVÁČ et al., 2018),

2/ absence of uniform biostratigraphic zonation and regional Early-Middle Miocene chronostratigraphic (and sequence stratigraphic) division of Central Paratethys (e.g., HARZHAUSER & PILLER, 2007; PILLER et al., 2007; HILGEN et al., 2012; HOHENEGGER et al., 2014; SANT et al., 2017; KOVÁČ et al., 2018), especially of Early/Middle Miocene boundary, as well as of Karpatian and Badenian regional stages (HOLCOVÁ et al., 2018; KOVÁČ et al., 2018). This prevents reliable stratigraphic correlation to be made based solely on biostratigraphic data. As well,

3/ assumption that initial transgression may be diachronous across the NCB (as it is diachronous across the southern margin of Pannonian Basin and across other Central European basins; MANDIC et al., 2012, 2019b; SANT et al., 2017) and/or that different parts of NCB could have been initialy flooded during different Early-Middle Miocene transgressive pulses of Central Paratethys (MANDIC et al., 2012, 2019b; SANT et al., 2017; HERNITZ KUČENJAK et al., 2018; KOVÁČ et al., 2018).

Excellent Mt. Požeška gora (Slavonian Mts. complex, Croatia) outcrop conditions (Croatian Geological Survey data) enable analysis of continuous transition from basal NCB Ottnangian–Karpatian alluvial coarse-grained deposits ("Daranovac unit") with aeolian siltstones, through Lower Badenian SPBLS brackish-lacustrine deposits ("Košćević unit"; HAJEK-TADESSE et al., 2009; MANDIC et al., 2019a) into Middle Badenian Central Paratethys marine deposits (offshore marls – "Vejalnica unit") with intercalated pyroclastics (ŠPARICA et al., 1979, 1980; PAMIĆ, 1997; HAJEK-TADESSE et al., 2009). However, the above mentioned stratigraphic ranges (KOVAČIĆ & PAVELIĆ, 2017) are uncertain. Therefore, integrated biostratigraphic (calcareous plankton) and high-precision geochronological (EARTHTIME initiative) studies are being conducted on Mt. Požeška gora marine and pyroclastic deposits. Determination and constraint of the age (time-stratigraphic correlation), stratigraphic relationships, and time-framed palaeoenvironments of Mt. Požeška gora deposits should:

1/ provide clues for the timing of the Central Paratethys initial transgression in the NCB,

2/ add new high-resolution data necessary for reconstructing Early–Middle Miocene syn-rift stratigraphic evolution of the NCB (with potential tectono-eustatic implications),

3/ provide new high-resolution data required for calibration and synchronization of NCB and in general Central Paratethys biostratigraphic zonation scheme(s)/bioevents, and

4/ provide Central Paratethys and Pannonian Basin chronostratigraphic (and sequence stratigraphic) implications.

Keywords: *Miocene, North Croatian Basin, transgression, time-stratigraphic correlation, Central Paratethys*

References

AVANIĆ, R. (2012): Litostratigrafske jedinice donjeg miocena sjeverozapadne Hrvatske [Lower Miocene lithostratigraphic units from north-western Croatia – in Croatian, with an English Abstract]. Unpubl. PhD Thesis, Faculty of Science, University of Zagreb, 162 p.

BALÁZS, A., MATENCO, L., MAGYAR, I., HORVÁTH, F. & CLOETHING, 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.

BRLEK, M., IVEŠA, Lj., BRČIĆ, V., SANTOS, A., ĆORIĆ, S., MILOŠEVIĆ, M., AVANIĆ, R., DEVESCOVI, M., PEZELJ, Đ., MIŠUR, I. & MIKNIĆ, M. (2018): Rocky-shore unconformities marking the base of Badenian (Middle Miocene) transgressions on Mt. Medvednica basement (North Croatian Basin, Central Paratethys). Facies, 64: 25. doi: 10.1007/s10347-018-0537-0.

ĆORIĆ, S., PAVELIĆ, D., RÖGL, F., MANDIĆ, 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). Geologia Croatica, 62, 31-43.

de LEEUW, A., TULBURE, M., KUIPER, K.F., DOBRINESCU, M.C.M., STOICA, M. & KRIJGSMAN, W. (2018): New $^{40}Ar/^{39}Ar$, magnetostratigraphic and biostratigraphic constraints on the termination of the Badenian Salinity Crisis: Indications for tectonic improvement of basin interconnectivity in Southern Europe. Global and Planetary Change, 169, 1-15.

HAJEK-TADESSE, V., BELAK, M., SREMAC, J., VRSALJKO, D. & WACHA, L. (2009): Early Miocene ostracods from the Sadovi section (Mt Požeška gora, Croatia). Geologica Carpathica, 60, 251-262.

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.

HERNITZ KUČENJAK, M., PREMEC FUČEK, V., KRIZMANIĆ, K., TADEJ, J., ZLATAR, S. & MATOŠEVIĆ, M. (2018): Karpatian and Badenian transgression in Croatian part of the Pannonian Basin System (biostratigraphy and palaeoenvironments). Forams 2018, Temporary Abstracts Collection, Edinburgh, 273-274.

HILGEN, F.J., LOURENS, L.J. & VAN DAM, J.A. (2012): The Neogene Period. In: GRADSTEIN, F.M. & OGG, J.G., SCHMITZ, M.D. & OGG, G.M. (eds.): The Geologic Time Scale 2012, 2 Volume Set. Elsevier, New York, 923-978.

HOHENEGGER, J., ĆORIĆ, S. & WAGREICH, M. (2014): Timing of the Middle Miocene Badenian stage of the Central Paratethys. Geologica Carpathica, 65, 55-66.

HOLCOVÁ, K., DOLÁKOVÁ, N., NEHYBA, S. & VACEK, F. (2018): Timing of Langhian bioevents in the Carpathian Foredeep and northern Pannonian Basin in relation to oceanographic, tectonic and climatic processes. Geological Quarterly, 62, 3-17.

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.

KOVÁČ, M., HALÁSOVA, E., HUDÁČKOVA, N., HOLCOVÁ, K. & HYŽNÝ, M. (2018): Towards better correlation of the Central Paratethys regional time scale with the standard geological time scale of the Miocene Epoch. Geologica Carpathica, 69, 283-300.

KOVAČIĆ, M. & PAVELIĆ, D. (2017): Neogene stratigraphy of Slavonian Mountains. In: KOVAČIĆ, M., WACHA, L. & HORVAT, M. (eds.): Field Trip Guidebook: Neogene of Central and South-Eastern Europe. Zagreb: Hrvatsko geološko društvo, 5-9.

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.

MANDIC, O., HAJEK-TADESSE, V., BAKRAČ, K., REICHENBACHER, B., GRIZELJ, A. & MIKNIĆ, M. (2019a): Multiproxy reconstruction of the middle Miocene Požega palaeolake in the Southern Pannonian Basin (NE Croatia) prior to the Badenian transgression of the Central Paratethys Sea. Palaeogeography, Palaeoclimatology, Palaeoecology, 516, 203-219.

MANDIC, O., RUNDIĆ, L., ĆORIĆ, S., PEZELJ, Đ., THEOBLAT, D., SANT, K. & KRIJGSMAN, W. (2019b): Age and mode of the Middle Miocene marine flooding in the Pannonian Basin - constraints from central Serbia. Palaios, 34, 71-95.

MARKOVIĆ, F. (2017): Miocenski tufovi Sjevernohrvatskoga bazena [Miocene tuffs from North Croatian Basin – in Croatian, with an English Abstract]. Unpubl. PhD Thesis, Faculty of Science, University of Zagreb, 174 p.

PAMIĆ, J. (1997): Volcanic rocks of the Sava–Drava interfluve and Baranja in Croatia. Monograph, Nafta, Zagreb, 192 p. (in Croatian).

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.

PILLER, W. E., HARZHAUSER, M. & MANDIĆ, O. (2007): Miocene Central Paratethys stratigraphy – current status and future directions. Stratigraphy, 4, 151-168.

SANT, K., V., PALCU, D., MANDIĆ, 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.

ŠPARICA, M., JURIŠA, M., CRNKO, J. & ŠIMUNIĆ, A. (1979): Basin geological map of SFRJ 1:100000, sheet Nova Kapela. Savezni geološki zavod, Beograd.

ŠPARICA, M., JURIŠA, M., CRNKO, J., ŠIMUNIĆ, A., JOVANOVIĆ, Č. & ŽIVANOVIĆ, D. (1980): Basic geological map of SFRJ 1:100000, sheet Nova Kapela, explanatory notes. Savezni geološki zavod, Beograd, 1-55 p. (in Croatian).

Sedimentary Record of the Submerged Late Quaternary Paleoenvironments Preserved in a Silled Karst Basin (Lošinj Channel, Adriatic Sea)

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Submerged paleoenvironments have become a popular topic among the scientific community due to their relevance for the interpretation of the future sea level and climate changes and the assessment of coastal flooding. Numerous present-day shelf seas were formed by marine transgression after the Last Glacial Maximum (LGM) and have transitioned from terrestrial to marine environment and vice versa multiple times during the Quaternary glacial-interglacial cycles. Adriatic sea was no exception. Here we present the results of a comprehensive research conducted in the submerged Lošinj Channel basin, located between the islands Cres and Lošinj in the northern part of the eastern Adriatic coast. Two sediment cores (LK-12, LK-15) were extracted and analyzed in detail. The combined measurements of magnetic susceptibility, grain size, mineralogy and geochemistry (XRF core scanning, total nitrogen, organic and inorganic carbon) were performed. Paleontological data and AMS ^{14}C dating results enhanced interpretation of the obtained sediment core data. High-resolution seismic methods gave us an additional insight into the sedimentary infill of this nowadays submerged basin. Investigated sediment succession in the Lošinj Channel revealed significant paleoenvironmental changes in relation to the Lošinj Channel sill depth (-50 m) and the Late Quaternary sea level and climate changes.

Our findings include the first detailed reconstruction of the presumed MIS 5a marine sediment sequence along the eastern Adriatic coast and the existence of an isolated

MIS 3 paleolake ("Lošinj paleolake"). During the LGM a typical karst feature (karst polje) was formed. A high resolution post-LGM sediment sequence was also investigated. During Allerød a brackish water lacustrine environment developed ("Lošinj marine paleolake") with the sea-water seepage through the karstified sill, while marine sedimentation started during Holocene (10.5 cal ka BP). Conducted research in Lošinj Channel offers a valuable new information for constraining the Late Quaternary paleoenvironmental and sea level changes along the eastern Adriatic coast. Due to the long time span (MIS 5-Holocene) of extracted sediment cores, the Lošinj Channel data are also significant on the wider regional scale.

Keywords: paleoenvironments, Late Quaternary, Lošinj Channel, sediment cores, high-resolution seismics

Late Triassic Terrestrial Phase Signature and its Correlation Through Selected Karst Dinaridic Sections

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The Triassic succession of Karst Dinarides is characterized with a significant terrestrial phase caused by the regional uplift of the Adria Microplate. Data collected from studied Karst Dinaridic sections indicate that this uplift occurred most probably during the Late Ladinian. Various intensity of denudation and/or karstification processes affected emergent area forming an uneven palaeorelief surface built up of the exposed remnants ranging from the Lower to the Middle Triassic strata, covered, partly, by the terrestrial deposits. Thus, in the Gorski kotar section the Upper Scythian silty dolomitic limestones ("*Campiler Schichten*") (ĐURĐANOVIĆ, 1967) are overlain by the Main Dolomite sequence, starting with a few centimeters thick interval of Lower Norian transgressive breccia, containing fragments of the Upper Scythian silty dolomitic limestones. Here, terrestrial phase apparently ranges from the Late Scythian to the Early Norian. In the Baške Oštarije secton after few decimeters thick interval of regressive breccias containing fragments of Anisian limestones, terrestrial phase is marked with few tens of meters thick interval of Ladinian-Carnian fine-grained tuffaceous reddish siltstones, overlain by the whole Main Dolomite sequence. Here, terrestrial phase apparently ranges from the Anisian to the Early Norian. In the Svilaja section, the Upper Ladinian limestones are covered with a few meters thick interval of Upper Norian transgressive breccia, containing fragments with *Diplopora annulata* Schafhäutl (JELASKA et al., 2003). The breccia interval is overlain by the Main Dolomite sequence reduced in thicknes. Thus, it can be assumed that terrestrial phase ranges here from the Late Ladinian to the Late Norian. In the Vrace section, terrestrial phase is marked with a few tens of meters thick interval of Carnian carbonate bauxites and laterites (ŠINKOVEC, 1970), ending with a few meters thick interval of transgressive breccia, containing fragments of bauxites, laterites and/or Upper Ladinian limestones, overlain by the whole Main Dolomite sequence.

Here terrestrial phase ranges from the Late Ladinian to the Early Norian. Therefore, due to an overall, diachronous Norian transgression, the whole emergent area was flooded and shallow-water platform regime was restored. As interplay of various intensity of denudation, karstification and diachronous Norian transgression, respectively, terrestrial phases of apparently various lengths came into being.

Keywords: Triassic, terrestrial phase, Karst Dinarides

References

ĐURĐANOVIĆ, Ž. (1967): The Lower Trias of the Gorski Kotar region. Geološki vjesnik, 20, 107-110.

JELASKA, V., KOLAR-JURKOVŠEK, T., JURKOVŠEK, B. & GUŠIĆ, I. (2003): Triassic beds in the basement of the Adriatic-Dinaric carbonate platform of Mt. Svilaja (Croatia). Geologija, 46/2, 225-230.

ŠINKOVEC, B. (1970): Geology of the Triassic bauxites of Lika, Yugoslavia. Acta geologica, 7, 5-70.

Jurassic Paleoenvironmental Associations from the Marginal Depositional System of the Adriatic Carbonate Platform (Žumberak Mt., Croatia)

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A Jurassic marginal depositional system of the Adriatic carbonate platform was analyzed in order to determine its depositional architecture and mayor depositional controls. Based on facies characteristics, four paleoenvironmental associations have been distinguished: (1) Top of the platform; during the early and middle Early Jurassic the deposition took place mostly in the subtidal zone where successive coarsening-upward cycles were produced as the interplay of allocyclic and autocyclic depositional processes, (2) Upper foreslope; during the late Early Jurassic the newly formed Adriatic carbonate platform experienced extensional faulting in its northeastern part in connection with rifting processes due to opening of the Dinaridic branch of the Neo-Tethys, which led to formation of the platform slope (ŠIKIĆ & BASCH, 1975; ŠIKIĆ et al., 1979). The occurrence of calcitized radiolarians, protoglobigerinids and skeletal fragments of pelagic bivalves or their prodissoconchs clearly points to deeper water conditions, (3) Toe-of slope; from the late Early Jurassic to the early Late Jurassic faulting induced periodic seismic activity triggered multiple mechanical disintegration of the platform slope resulted in gravity mass movements along the slope and accumulation of calciturbidite interlayers with T-a Bouma features in the toe-of-slope environment.

Also, sporadic more intense seismic shocks produced angular fragments of already consolidated deposits on the platform slope that were gravitationally moved down along the slope, forming a thick carbonate breccia wedge in the toe-of-slope environment. A multiple accumulation process can be assumed since pretty thick interval of breccia wedge was formed, and (4) Basin; thin beds represent autochthonous pelagic carbonate mud deposition ("pelagic rain") within the deep-water environment distant from the platform margin, as indicated by the lack of any sedimentary structures and coarse-grained bioclastic intercalations. More argillaceous intervals correspond to increased influx of fine-grained siliciclastic detritus, probably derived from the north, i.e. from the Hercynian ranges (PAMIĆ et al., 1998). Therefore, the environmental changes are interpreted to be related to tectonic activity as a consequence of regional extensional movements, connected with the opening of the Dinaridic branch of the Neo-Tethys. These extensional movements resulted in multi-stage drowning on the northeastern part of the Adriatic carbonate platform, leading to its gradual back stepping and accordingly expanding of the Dinaridic branch of the Neo-Tethys basin (BABIĆ, 1976).

Keywords: Jurassic, Adriatic carbonate platform margin, Žumberak Mt.

References

BABIĆ, LJ. (1976): Migration of the boundary between "inner" and "outer" Dinaric zones. The 8th Yugoslav Geological Congress, 2, 45-52.

PAMIĆ, J., GUŠIĆ, I. & JELASKA, V. (1998): Geodynamic evolution of Central Dinarides. Tectonophysics, 297, 273-307.

ŠIKIĆ, K. & BASCH, O. (1975): Geological events from Paleozoic to Quaternary in the western part of Zagreb area. 2. godišnji znanstveni skup sekcije za primjenu geol., geofiz., geokem., Znanstveni savjet za naftu JAZU Zagreb (A), 5, 69-86.

ŠIKIĆ, K., BASCH, O. & ŠIMUNIĆ, A. (1979): Basic geological map of Yugoslavia 1:100 000, Geology of the Zagreb sheet. Institut za geološka istraživanja Zagreb, Savezni geološki zavod Beograd, 81 p.

Population Dynamics of Benthic Foraminifera Ammonia Tepida (Cushman): Data from Rogoznica Lake

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The periods with low dissolved oxygen concentrations in bottom waters in coastal areas can have strong impacts on benthic ecosystems. Among the meiofauna living in these environments, benthic foraminifera are often the most tolerant to low oxygen levels. Some species are able to survive complete anoxia for weeks to months.

Lake Rogoznica is located on the Gradina peninsula and is not directly connected with the open sea. There is, however, marine influence through the porous limestone rocks. Due to its position, the lake has very peculiar ecological characteristics, quite different from those of other coastal salt lakes in the Mediterranean. A seasonally stratified seawater characterizes this "lake", the surface water is similar to waters of the adjacent Adriatic Sea in temperature and salinity, whereas bottom water is enriched in nutrients and dissolved organic carbon and deprived of oxygen (PJEVAC et al., 2014).

In 2010 a short core (50 cm long) has been recovered from 9 m of water depth. Sediments were sliced into 2 cm thick subsamples and submitted to geochemical and granulometric analysis. Micopaleontological analysis on residues greater than 63 μm, were done on samples from certain levels only (intervals: 4–6, 16–18, 26–28 and 36–38 cm). In all samples, only *Ammonia tepida* (CUSHMAN) tests were found. Representatives of the species are effective grazers of microalgae and their physiology, successful reproduction and survival are driven by factors including oxygen and food availability, food quality or environmental temperature (MURRAY, 2006).

How to explain the presence of tests in all studied samples when periods of oxygen deficiency occur regularly?

In order to get some answer, the analysis of survivorships and fecundity of *A. tepida* population were performed. The maximum test diameter of each specimen was measured under stereoscopic microscope (Olympus SZx7) using QuickPHOTO camera3.0 software. The diameters vary from 137 to 368 μm. In all populations, the tests with diameters between 180 and 200 μm are the most abundant, less numerous are specimens with the largest tests (220 - 260 μm), whereas those with small tests are rare. A bimodal distribution was recorded. In seasonally mixed assemblages (2 cm thick core interval), a possible explanation for such distributions is that reproduction and growth is so rapid that juveniles are seen as size class 180–200 μm in one season, and in size class 220–260 μm in another. The opportunistic foraminifera have fit their life strategy to time of "good season", postponing maturity time and reproduction to the period with oxygenated bottom water and sediments (shallow infaunal life habitats, MURRAY, 2006). Taking into account the newest data about surviving around 28 days of anoxia (LeKIEFFRE et al., 2017), their generative time (one season), transport and dormant – stage (ALVE & GOLDSTEIN, 2010) of propagules, representatives of this species can be present is such stressful environment all year (with different abundances).

Keywords: *population dynamics, Ammonia tepida, Rogoznica Lake*

References

ALVE, E. & GOLDSTEIN, S.T. (2010): Dispersal, survival and delayed growth of benthic foraminiferal propagules. Journal of Sea Research, 63/1, 36-51.

LeKIEFFRE, C., SPANGENBERG, J.E., MABILLEAU, G., ESCRIG, S., MEIBOM, A. & GESLIN, E. (2017): Surviving anoxia in marine sediments: The metabolic response of ubiquitous benthic foraminifera (*Ammonia tepida*). PLoS One, 12/5, e0177604.

MURRAY, J. (2006): Ecology and Application of Benthic Foraminifera. Cambridge University Press, Cambridge, 426 p.

PJEVAC, P., KORLEVIĆ, M., BERG, J.S., BURA-NAKIĆ, E., CIGLENEČKI, I., AMANN, R. & ORLIĆ, S. (2014): Community shift from phototrophic to chemotrophic sulfide oxidation following anoxic holomixis in a stratified seawater Lake. Applied Environmental Microbiology, 81, 298-308.

Paleotemperature and Paleoprecipitation Estimations at South Peloponnese, Greece, During Last About 2500 Years

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This research presents paleotemperature and paleoprecipitation estimations derived using paleosol-based paleoclimate chemical proxies as well as other relevant results. According to the considered literature, paleosol-based proxies are considered very helpful in improving our understanding of long-term environmental changes (TABOR & MYERS, 2015). Compared to marine records, paleosol-based paleoclimate proxies have lower temporal resolution. Nevertheless the offer a more direct tool for estimating paleoclimatic conditions as soils formation takes place on Earth's surface in direct contact with atmosphere and other climate system's components (SHELDON & TABOR, 2009).

This research focuses on a paleosol hosted in a doline, located in the South Peloponnese, Greece. This area was chosen according to the literature, as it represents one of the most significant Greece regions for paleoenvironmental research. Part of the samples was dated by the Optically Stimulated Luminescence (OSL) dating technique, in order to deduce the chronological framework of paleoenvironmental changes. The rest of the samples were used for performing Inductively Coupled Plasma Mass Spectrometry (ICP-MS) elemental analyses and X-ray diffraction (XRD) mineral analyses. Obtained results will be presented and correlated with other research findings. Another parameter studied during this research was sedimentation rate. This parameter is closely connected with paleoenvironmental conditions and can be used for interpreting paleoprecipitation estimations.

According to the gained results the oldest paleosol layer age is estimated at about 2.5 ka while the youngest one is about 0.35 ka. Paleotemperature estimations propose that the mean temperature was constant throughout the whole period at about 15 °C with the annual precipitation of about 1200 mm y^{-1}. Detailed description of the performed research and findings will be presented and discussed.

Keywords: Paleotemperature, paleoprecipitation, paleosol proxies, South Peloponnese, Greece

References

SHELDON, N.D. & TABOR, N.J. (2009): Quantitative Paleoenvironmental and Paleoclimatic Reconstruction Using Paleosols. Earth-Science Reviews, 95, 1-52.

TABOR, N.J & MYERS T.S. (2015): Paleosols as Indicators of Paleoenvironment and Paleoclimate. Annual Review of Earth and Planetary Sciences, 43, 333-361.

Chemical Status at Groundwater Monitoring Stations and Analysis of the Implementation of Measures within 2016-2021 Plan in the Danube River Basin District

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The analysis of groundwater chemical status in the Danube river basin district (RBD) is based on the results of the national monitoring of groundwater chemical status which Hrvatske vode performs each year, and related to the

results from the 2014-2017 period. 20 grouped groundwater bodies (GWB) have been identified in the Danube RBD, of which 5 water bodies in karst aquifers and 15 water bodies in alluvial aquifers. The grouped water bodies are subject to surveillance monitoring in order to assess the chemical status. Operational monitoring is carried out in order to identify the chemical status of all GWBs for which the analysis of RBD characteristics has identified a risk of failure to achieve the water protection objectives and at which a change of status during the implementation of the programme of measures is monitored. In the GWBs where a significant and sustained upward trend of pollutant concentration under the impact of anthropogenic activities has been identified, the starting points for the monitoring and identification of trends, their change, and the starting points for trend reversals are defined. The chemical status at groundwater monitoring stations is assessed based on the indicators set out in Annex 6 to the Regulation on water quality standard (OG 73/13, 151/14, 61/16, 80/18; hereinafter: the Regulation), which are monitored within surveillance and operational monitoring: nitrates and active substances in pesticides, individual and total, as well as specific pollutants. The chemical status of GWBs is classifed in two categories: good and bad. It is determined in accordance with the methodologies from the River Basin Management Plan (RBMP).

The results from the monitoring stations that exceed the quality standard or the limit values are classified as bad status at a monitoring station, as opposed to the results that do not exceed the limit values of specific pollutants, i.e. the values of groundwater quality standard that indicate good status at a monitoring station. The status at a monitoring station is an initial indicator that a monitoring station is in bad status, a sign that something is going on in a GWB, requiring measures for the GWB to remain in good status or to change from bad to good status. The scope of groundwater quality data used for status assessment is a slightly bigger than the scope of data available for the development of earlier management plans, but still with poor spatial availability of data. The purpose of this paper is to analyse the implementation of the RBMP 2016-2021 and to analyse the implementation of measures, as well as to propose new measures in the next planning cycle. This paper identifies groundwater-related significant water management issues.

Keywords: *national monitoring of groundwater chemical status, surveillance and operational monitoring, Regulation, pollutants, River Basin Management Plan*

References

GOVERNMENT OF THE REPUBLIC OF CROATIA (2013): Uredba o standardu kakvoće voda [Regulation on water quality standard], OG 73/13.

GOVERNMENT OF THE REPUBLIC OF CROATIA (2014): Uredba o izmjenama i dopuni Uredbe o standardu kakvoće voda [Regulation on Amendments to the Regulation on water quality standard], OG 151/14.

GOVERNMENT OF THE REPUBLIC OF CROATIA (2016): Plan upravljanja vodnim područjima 2016. - 2021. [2nd River Basin Management Plan (2016-2021)], OG 66/16.

GOVERNMENT OF THE REPUBLIC OF CROATIA (2016): Uredba o izmjenama i dopuni Uredbe o standardu kakvoće voda [Regulation on Amendments to the Regulation on water quality standard], OG 61/16.

GOVERNMENT OF THE REPUBLIC OF CROATIA (2018): Uredba o izmjenama i dopuni Uredbe o standardu kakvoće voda [Regulation on Amendments to the Regulation on water quality standard], OG 80/18.

Stratigraphy of the Latest Cretaceous to Palaeocene Platform Carbonate Succession of the Likva Section, Island of Brač, Croatia

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The Maastrichtian–Palaeocene Likva section was examined to reconstruct environmental changes and describe coral patch reefs across the K/Pg transition. A continuous, 50-m-thick succession of shallow-water platform carbonates encompassing the K/Pg boundary was studied to determine biostratigraphy of larger benthic and planktonic foraminifera, microfacies, sedimentology, and geochemistry (strontium-isotope stratigraphy). Studied succession indicates deposition within very shallow inner platform environments with coexisting rudists and scleractinian corals during the late Maastrichtian. The Cretaceous strata consist of: (1) lower part composed of

wackestone and floatstone with rudist fragments, peloids, ostracods, discorbid and large benthic foraminifera, and fenestral laminites deposited in the low-energy restricted shallow subtidal and intertidal environments; (2) middle part containing a brecciated surfaces with speleothems and blackened lithoclasts, indicating multiple subaerial exposures, accompanied by coral patch reefs with preserved globular and domal growth fabric characterised by intense weathering and reddish color; (3) upper part composed of the laminated fenestral micritic limestones with peloids, ostracods, discorbids, and rare thin-shelled rudist fragments overlain by grain-supported limestones with miliolids, peloids, intraclasts and rare planktonic foraminifera immediately below the K/Pg boundary level indicating temporary open marine influences.

The boundary is constrained between the last occurrence of the Maastrichtian larger benthic foraminifera and the first occurrence of the Danian planktonic and benthic foraminifera. The K/Pg boundary is characterized by a sediment bioturbation and a 2-cm-thick reddish-brown clayey mudstone, but due to the low biostratigraphic resolution question on existence of a possible short stratigraphic hiatus remained open.

The lowest 2-m-thick interval of the Palaeocene strata consists of burrowed micritic limestones with discorbids, ostracods and planktonic foraminifera deposited in more open marine environments. Planktonic foraminifera tentatively indicate basal Danian Zones P0–Pα. Above the horizon with pelagic influence (probably indicating short-term sediment starvation rather than deepening of the environment), a sudden return to micritic limestones with discorbids, ostracods and charophytes indicates re-establishment of the low-energy shallow subtidal conditions with nearshore brackish and freshwater influence comprising benthic foraminifera assemblage of the SBZ 1. Top of the section is characterised by the largest and best developed coral patch reef exposed and karstified during the following relatively long regional exposure event between these oldest Palaeocene and the overlying Palaeocene/Eocene deposits.

The Likva section with its prolonged shallow-marine deposition across the K/Pg boundary represents an important addition to the knowledge of the Adriatic Carbonate Platform stratigraphy, indicating that its upper stratigraphic limit is locally extended to the earliest Palaeocene.

Keywords: *Stratigraphy, Latest Cretaceous, Palaeocene, Carbonate succession, Brač, Croatia*

Bio- and Chemostratigraphy of the Lower Cretaceous Carbonate Platform Deposits of Mt. Svilaja, Croatia

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Two chronostratigraphically equivalent successions (Milešina and Jarebinjak) of the Cretaceous (Aptian–Albian) Adriatic Carbonate Platform (AdCP) deposits exposed only 7 km apart at Mt. Svilaja (Croatia) differ significantly in their facies composition and Aptian emersion features. Both successions reveal similar microfacies characteristic of the Lower Aptian oceanic anoxic event OAE 1a interval, but differ in their thickness. They are both composed of wackestones and oncoid–bioclastic floatstones with *Bacinella irregularis* RADOIČIĆ and requieniid rudist fragments. However, the beginning of the Lower Aptian succession at the Jarebinjak locality has a species-rich rudist assemblage embedded within bioclastic floatstones. On weathered outcrop surfaces, caprinid, caprotinid and probably monopleurid rudist transverse sections can be recognized, indicating an Early Aptian age: *Offneria* sp., *Praecaprina* sp., and *Glossomyophorus costatus* MASSE et al. The caprinid assemblages, as well as the thicker Lower Aptian interval at Jarebinjak, indicate an influence of open sea circulation and a greater accommodation space, respectively, probably as a result of synsedimentary tectonism.

At the Milešina locality, several metres thick successions of algal wackestones and peloid–miliolid packstone–grainstones to wackestones directly overlie Lower Aptian strata. Evidence for regressive trends and subaerial exposure, which are common in this horizon elsewhere in the AdCP region, are also present here, but as thin layers of breccia or abundant charophytes, reflecting an increased fresh water influence. In contrast, at the Jarebinjak locality, this horizon exhibits more distinct regressive trends, evidenced as 7 to 8 thin beds of clay and marl associated with subaerial exposure features. The limestone beds within this occasionally emergent horizon are characterized by algal wackestones and rare species of *Mesorbitolina* foraminifera.

Above the emergence horizon, the Upper Aptian–Lower Albian successions at both localities contain micritic limestones with variable amounts of calcareous mud, peloids and skeletal grains (rare miliolids and ostracods). These deposits irregularly alternate with thin layers of peloid–intraclastic–skeletal packstone–grainstones and peloid wackestone–packstones with fragments of molluscs (mostly gastropods) and benthic foraminifera (e.g., *Mesorbitolina texana* (ROEMER)). Increased fresh water influence is indicated in the Lower Albian level at Milešina by abundant charophytes, identified as *Munieria grambasti sarda* CHERCHI et al. The strata with charophytes also contain dasyclad alga *Salpingoporella*, indicating that fossil dasyclads can inhabit brackish environments.

Stratigraphic determinations were based on benthic microfossil assemblages, including foraminifera and dasyclad algae, which are very good paleoenvironmental indicators, but their usefulness in biostratigraphy can suffer from low resolution and poor correlation with standard biochronologic scale based on planktonic foraminifera, calcareous nannoplankton and ammonites. Therefore, this research also included a chemostratigraphic study involving stable isotope analyses of homogenous micritic matrix samples. Despite limitations due to potential masking of global marine isotope signatures in restricted depositional environments and subsequent diagenetic modifications, the documented variations in carbon isotope compositions, especially when considered relative to oxygen isotope values, proved useful for stratigraphic correlation between the examined successions and for improving their age determination. Examples include refinement in the placement of the Barremian–Aptian boundary, recognition of the OAE 1a (in the Lower Aptian strata) and OAE 1b (straddling the Aptian–Albian boundary) intervals, and correlation with carbon-isotope stages C1 to C8 of MENAGATTI et al. (1998). The results provide critical information for correlating these Mt. Svilaja strata to other coeval successions that span the time interval of major global oceanographic changes and carbon-cycle perturbations associated with Early Cretaceous oceanic anoxic events.

Keywords: *biostratigraphy, chemostratigraphy, Lower Cretaceous carbonate deposits, Mt. Svilaja, Croatia*

References

MENAGATTI, A.P., WEISSERT, H., BROWN, R.S., TYSON, R.V., FARRIMOND, P.A.S. & CARON, M. (1998): High-resolution $\delta^{13}C$ stratigraphy through the early Aptian "Livello Selli" of the Alpine Tethys. Paleoceanography, 13, 530-545.

Late-Pleistocene – Holocene Climate Variability as a Driver of Human Settlement Change in the Central Adriatic Sea

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In this study we cross-check Palaeoclimatic evidence from two marine cores retrieved in the Central Adriatic Sea with environmental and cultural evidence from an archaeological sequence on the Island of Korčula (Central Dalmatia), which is notable for the presence of Vela Spila, a cave inhabited since 18.5 ka BP starting with Upper Palaeolithic cultures. There is a hiatus in occupation of the cave from 15–9.5 ka BP (FARBSTEIN et al., 2012). In order to better understand the drivers of this and other settlement changes observed in the cave, we compare the existing archaeological and geoarchaeological records from the site with climate proxies from the PRAD1-2 core (PIVA et al., 2008) and the POMO core, which was taken during the ISMAR-CNR CaDi 2006 cruise (forthcoming). Both cores were drilled in the Mid-Adriatic Deep and represent the two available marine records closest to Korčula. Although they have already been partly published, the 17-7 ka BP range is analyzed in greater detail in this work. For the POMO core, we obtain a new, detailed suite of stable oxygen isotope ($\delta^{18}O$) and AMS ^{14}C measurements on planktonic foraminifera. For both cores we use a new Bayesian age-depth model. The tephra layers recognized in the stratigraphy can be used as precise stratigraphic markers; in particular several ash layers from the POMO core.

As a result, we obtained a higher resolution, more local climate record applicable to Vela Spila cave to supplement other, regional records (e.g. AUFGEBAUER et al., 2012; SIANI et al., 2013). The climatic record obtained in

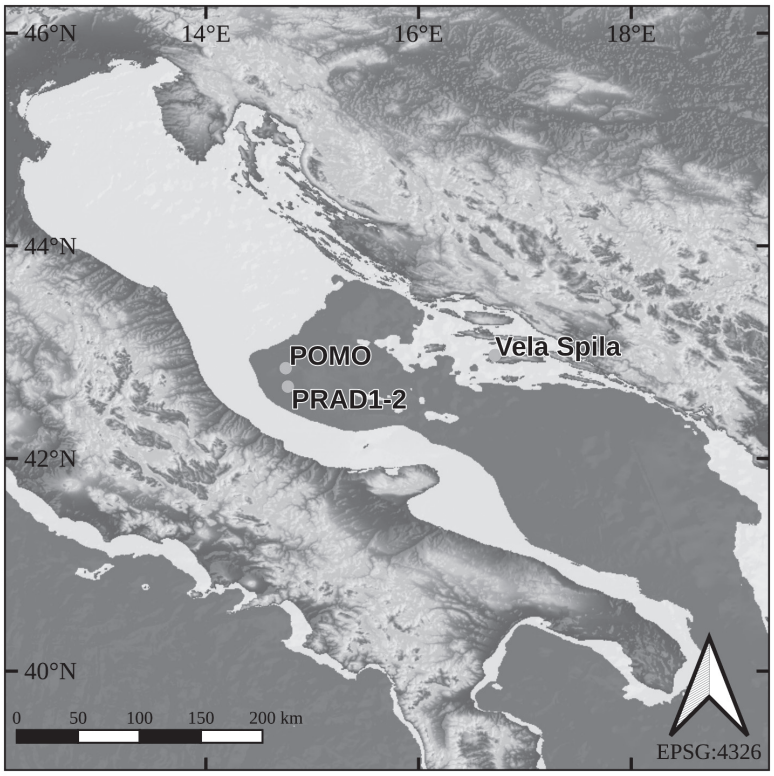

Figure 1. Study area showing approximate locations of Vela Spila prehistoric cave and the PRAD 1-2 and POMO cores. The border between the light and dark areas in the sea corresponds the 120 m isobath, thought to roughly approximate sea levels at the last glacial maximum. The PRAD 1-2 core was taken in 185.5m depth of water with a drilled length of 71.2 m (PIVA et al., 2008). The POMO core from the the ISMAR-CNR CaDi 2006 cruise (forthcoming) was taken in 258 m depth of water, with a drilled length of 3.6 m.

this work, analyzed in association with microfaunal data from the same cores and cross checked with global climate proxies such as Greenland Ice cores (NGRIP PROJECT MEMBERS, 2004) allows us to weight the importance of possible settlement change drivers such as climate change, sea-level rise, and local effects of explosive volcanic eruptions in the Mediterreanean region. In particular, the possible environmental factors responsible for the phase of cave abandonment have been analyzed, as well as those chronologically connected to the major phases of cultural change such as the transition from Palaeolithic to Mesolithic and from Mesolithic to Neolithic. Moreover, the climatic record was used to supplement our knowledge of the relationships between human settlement and sea-level change previously obtained through the reconstruction of submerged palaeolandscapes.

The results indicate that significant changes in climate would have been experienced by the inhabitents of Vela Spila, however the significance of sea-level change in the area (FORENBAHER, 2002) and its effect on the flat, relatively featureless terrain to the north and south of present-day Korčula must not be underestimated in their likely effect on the hunting grounds preferred by Palaeolithic hunters.

Keywords: Croatia, geoarchaeology, climate change, oxygen isotopes, prehistory

References

AUFGEBAUER, A., PANAGIOTOPOULOS, K., WAGNER, B., SCHAEBITZ, F., VIEHBERG, F.A., VOGEL, H., ZANCHETTA, G., SULPIZIO, R., LENG, M.J. & DAMASCHKE, M. (2012): Climate and Environmental Change in the Balkans over the Last 17 Ka Recorded in Sediments from Lake Prespa (Albania/F.Y.R. of Macedonia/Greece). Quaternary International, 274 (1): 122-35.

FARBSTEIN, R., RADIĆ, D., BRAJKOVIĆ, D. & MIRACLE, P.T. (2012): First Epigravettian Ceramic Figurines from Europe (Vela Spila, Croatia). PLOS ONE 7 (7): e41437. https://doi.org/10.1371/journal.pone.0041437.

FORENBAHER, S. (2002): Prehistoric Populations of the Island of Hvar – an Overview of Archaeological Evidence. Collegium Antropologicum, 26 (1): 361-78.

NGRIP PROJECT MEMBERS (2004): High-Resolution Record of Northern Hemisphere Climate Extending into the Last Interglacial Period. Nature, 431 (7005): 147-51. https://doi.org/10.1038/nature02805.

PIVA, A., ASIOLI, A., SCHNEIDER, R.R., TRINCARDI, F., ANDERSEN, N., COLMENERO-HIDALGO, E., DENNIELOU, B., FLORES, J.A. & VIGLIOTTI, L. (2008): Climatic Cycles as Expressed in Sediments of the PROMESS1 Borehole PRAD1-2, Central Adriatic, for the Last 370 Ka: 1. Integrated Stratigraphy: STRATIGRAPHY OF PROMESS1 BOREHOLE PRAD1-2. Geochemistry, Geophysics, Geosystems 9 (1): n/a-n/a. https://doi.org/10.1029/2007GC001713.

SIANI, G., MAGNY, M., PATERNE, M., DEBRET, M. & FONTUGNE, M. (2013): Paleohydrology Reconstruction and Holocene Climate Variability in the South Adriatic Sea. Climate Of The Past, 9 (1) 499-515. https://doi.org/10.5194/cp-9-499-2013.

Identification of Most Suitable Area for Crushed Stone Aggregates Using GIS Method: A Case Study in Koprivnica Križevci County, Croatia

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Aggregate is a low unit-value mineral commodity. Transport costs for aggregate from the mine site to the point of use is a large fraction of the resource cost to users. Production sites for aggregate occur where suitable source materials exist and where transportation and market conditions are favourable. The increasing demand for aggregate and the difficulty of developing and permitting new sites and of renewal of permits on existing sites of aggregate production indicates that aggregate will be supplied from sources yet to be developed or delineated in many areas.

The purpose of this paper is to assess the crushed rock aggregate resources in the Koprivnica Križevci County and to delineate areas with aggregate resources. The suitable site selection is performed using the geographical information system (GIS) approach with weighted overlay analysis. In the Koprivnica Križevci County gravel and sands and crushed stone aggregates are quarrying from around 30 exploitation sites (KRUK et al., 2015).

Map correlation and map-integration processes were made using ArcSDM extension tool (Weights of evidence) to define relationships between spatial layers and combine predictor factors in supporting a hypothesis. The response variable is the set of point locations of current aggregate and stone quarries or gravel and sand pits (termed training sites), and the predictor variables which are thematic map layers showing transportation network patterns, population density distribution, maps of geological mineral potential, and areas of mineral exploitation restrictions defined by Master plans of the county and production information.

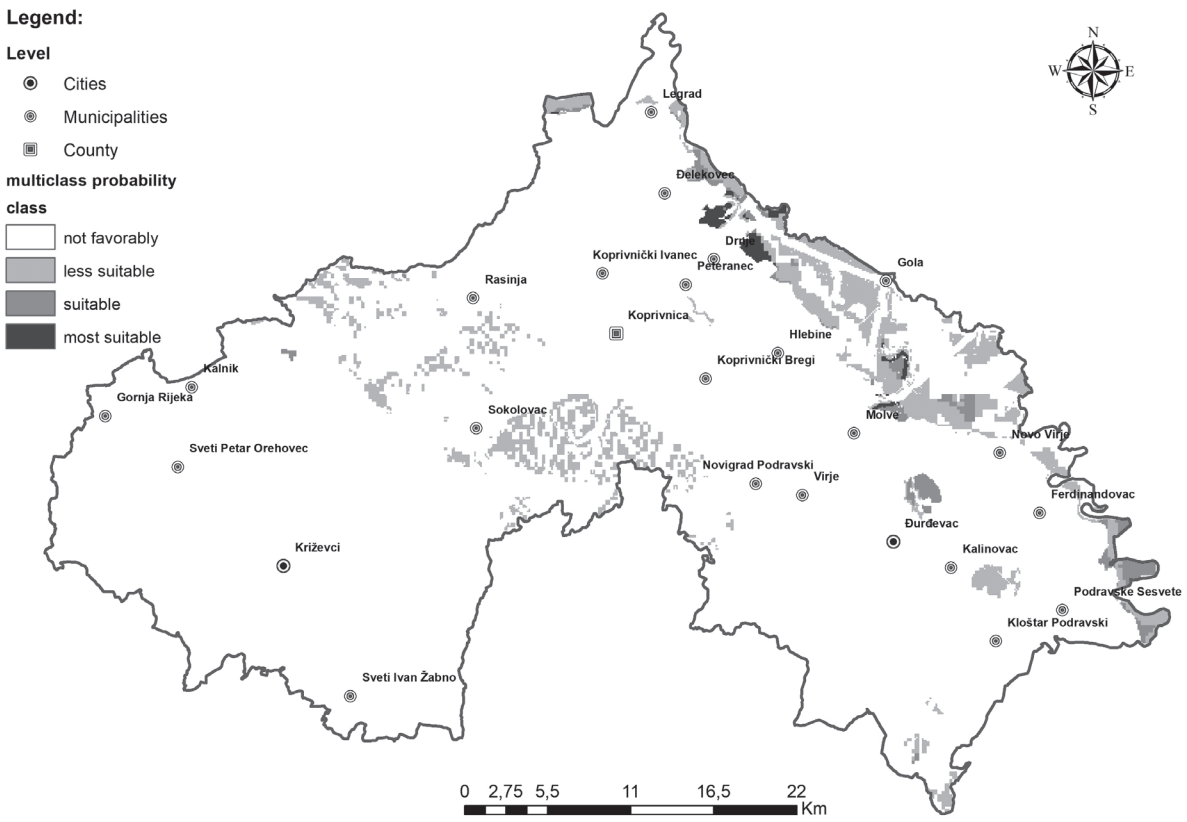

Figure 1. Results of multiclass model, delineated the most suitable areas with aggregate resources in the Koprivnica-Križevci County.

The spatial correlation between all thematic data allowed us to prepare the final suitability map (Fig. 1). Based on the results of this paper, various aggregate potential areas in the Koprivnica Križevci County have been selected and each one has been assigned to categorie (suitable, moderately suitable and unsuitable) representing their suitability levels for future development in terms of the environmental constraints, availability of transport networks, current land use, and availability of mineral reserves. This analysis and classification provide important information for policy makers to decide on effective land and resource management plan, and for regional or state authorities in the process of granting licenses to operate a stone quarries or sand and gravel pits.

Keywords: *aggregate, geological potential, Koprivnica Križevci County, spatial planning, GIS*

References

KRUK, B., DEDIĆ, Ž., HEĆIMOVIĆ, I., KRUK, LJ., KOLBAH, S., ŠKRLEC, M., CRNOGAJ, S. & KOVAČEVIĆ GALOVIĆ, E. (2015): Rudarsko-geološka studija Koprivničko-križevačke županije [Mining – Geological study of Koprivnica Križevci County]. Fond stručne dokumentacije 61/14, Hrvatski geološki institut, Zagreb.

EuroLithos – Ornamental Stone Resources in Europe

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EuroLithos is a GEOERA research project on European Ornamental Stone Resources in Europe. Although ornamental stone is today an important raw material produced all over Europe, its use locally and regionally is decreasing, along with related knowledge, traditions and skills. EuroLithos was founded upon the premise that increased knowledge of the geological quality and historical use of natural stone in Europe can stimulate more sustainable use of this resource. EuroLithos will in turn benefit enterprise, promote cultural heritage, and contribute to developing effective and environmentally sound land-use practices.

The EuroLithos consortium is composed of 16 partners from 14 countries, collectively forming a strong and innovative research group. The Geological Survey of Norway (NGU, Norway) is a Project Lead, and the Croatian Geological Survey (HGI-CGS, Croatia) is one of the WP Leads, beside Laboratorio Nacional de Energia e Geologia (LNEG, Portugal) and Hellenic Survey of Geology and Mineral Exploration (H.S.G.M.E., Greece).

The Work Packages of the EuroLithos project include Project management (WP1, lead NGU), Dissemination, communication and stakeholders (WP2, lead NGU), Atlas of European ornamental stones (WP3, lead LNEG), Directory of ornamental stone properties (WP4, lead H.S.G.M.E.), Ornamental stone heritage (WP5, lead HGI-CGS) and link to Ornamental stone information platform (WP6, lead NGU).

EuroLithos challenges include increasing replacement of traditional stone materials with "cheapest on the market", decreasing competitiveness of small and medium-sized enterprises (SMEs), reduction of cultural heritage values and increasing environmental footprints.

EuroLithos concept include raising awareness and knowledge of the diversity of European ornamental stone resources, their importance to our landscapes and architecture, their quality and the environmental benefit of "short-travelled" resources.

EuroLithos impact include improving cross-European knowledge sharing, improving assessment for making good and sustainable choice of stone to construction projects and better competitive regime for European SMEs.

The main objective of the Work Package 5 in which lead beneficiary is HGI-CGS, is to establish guidance that can facilitate and aid the process of valorisation of stone resources. We believe that such tools will contribute to better maintenance of stone-built heritage, better conditions for SMEs and better protection of stone resources in land-use planning. The tools will address three aspects of stone heritage; the intrinsic value of stone quarries and quarry landscapes, the value of stones from their use in stone-built heritage, and the traditional crafts.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166.

Keywords: *ornamental stone, directory and database, heritage values, framework, Europe*

Crustal Section Across the North Adria Plate From Italian (Pesaro) to Croatian (Kvarner) Shorelines

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Based on interpretation of seismic data calibrated by wells, a new regional interpretation across upper crust beneath the Northern Adriatic Sea from Pesaro (Italian shoreline) to Kvarner Gulf (Croatian shoreline) is proposed (Fig. 1). Starting from the calibration point, seismic-stratigraphic facies was classified for the lithological units. The most recognizable reflectors, not always clear, are typical: the base of Plio-Quaternary (PQ) generally coincides with the Messinian erosional surface (MES), often reaching the Paleogene-Neogene sequences and the top of the Mesozoic carbonate succession. The base of the carbonates is also visible in many profiles, covering the thick Permo-Triassic (PT) clastic sequence.

From the west to the east, the profile shows several main geological structures characterizing the Adriatic Sea: i) the Northern Apennines frontal thrusts; ii) the corresponding foredeep basin filled by a thick PQ sequence; iii) the "build-up"-like structure along the margin between the Liassic/Cenozoic Adriatic pelagic sequence (on the west) and the Adriatic Carbonate Platform (on the east); iv) the frontal thrusts of the External Dinarides, represented by gentle anticlines of the carbonate platform succession that are probably detached from the basement.

The steep westward tilting of the common Adriatic foreland gently affects also the Adriatic Carbonate Platform. It is evident by Pliocene stratal terminations, onlapping the main Messinian unconformity, or the top of an Early Pliocene sedimentary unit. Moreover, erosional canyons, filled with several generations of various clinoform packages are very common in the Kvarner region. These canyons are probably incised during Messinian times, due to erosion, but infill patterns are also suggesting their relations with the large scale strike-slip faulting. Recent strike-slip related transpresssional and transtensional features are also evident in the Kvarner area.

This coast to coast type of regional study allows revelation of differing tectonic structures and stratigraphic relations across the Adriatic Sea, which typically cannot be reconstructed on a small, local scale. It shows that the pre- and syn-orogenic structures were sometimes reactivated during the post-orogenic phase, probably associated with large scale motions of Adria plate indicating still active neotectonic movements.

Acknowledgements

The study is partly supported by Croatian Scientific Foundation project HRZZ_IP-06-2016-1854 GEOSEKVA.

Keywords: Adriatic Plate, Apennines and Dinarides orogenic belts, intra-plate tectonics, seismostratigraphy

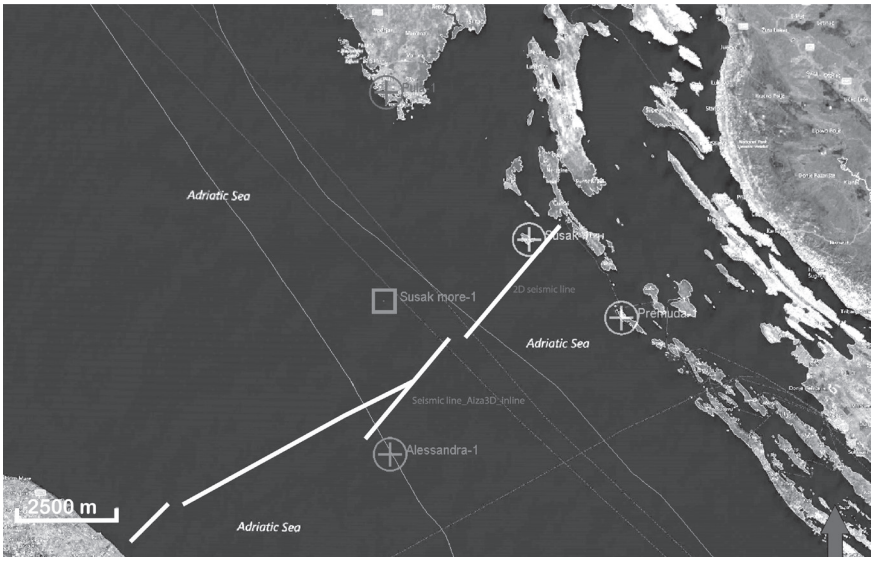

Figure 1. Map of the study area and of the interpreted seismic profiles.

References

DEL BEN, A. (2002): Interpretation of the CROP-M16 seismic section in the Central Adriatic Sea. Mem. Soc. Geol. It., 57, 327-333.

GRANDIĆ, S. (2009): Periplatform clastics of Crotian offshore and their petroleum geological significance. Nafta, 60, 503-511.

KORBAR, T. (2009): Orogenic evolution of the External Dinarides in the NE Adriatic region: a model constrained by tectonostratigraphy of Upper Cretaceous to Paleogene carbonates. Earth-Science Reviews, 96, 296-312.

Microplastic in the Sea Bottom Sediment

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Plastic is an irreplaceable material due to its favorable properties, however, it is also one of the most serious environmental issues, especially in the sea environments. Plastic particles arrive to the sea mostly from land sources, and degradation of larger pieces results in the creation of microplastic. Microplastic refers to plastic particles less than 5 mm in size (Fig. 1), which have become so widespread and can be found everywhere, on shores, in ice and water, living organisms and at the surface and bottom of seas and oceans. Microplastic poses a great danger to the environment especially to the living organisms and they are very difficult to remove from the sea due to their microscopic size. Once microplastic reach marine environment, marine organisms can ingest it as a food. Microplastic materials can adsorb heavy metals and various viruses and bacteria from the sea, which makes a significant problem when microplastic materials get into the food chain.

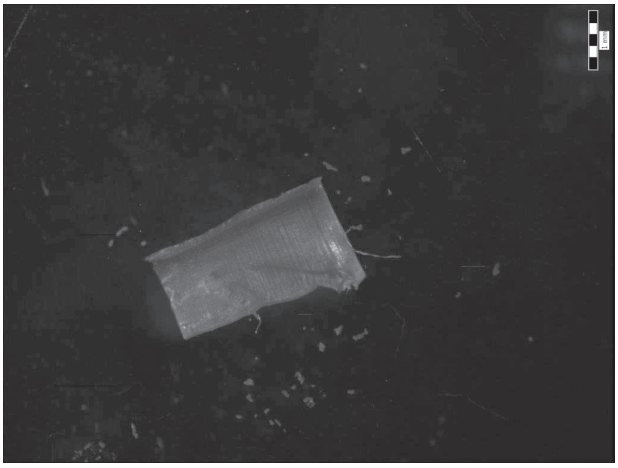

Figure 1. Microplastic particle found in the shelf sediment.

In order to determine if and to what extent microplastic is present in the shelf sediment, cores collected from the Mediterranean Sea were analyzed. Two cores were sampled from the bottom of the shelf of the southern coast of Sicily and the other two cores were collected from the shelf around the Tuscan islands. Only the top centimeter of the sediment was analyzed for the presence of microplastic. Sediment samples were dried and weighed, then wet sieved, first using a 1 mm mesh sieve and then 63 µm mesh sieve. Particles that were suspected to be microplastic were extracted from the sieve under microscope. Analyses were performed using the ATR method (Attenuated total reflection) on FTIR (Fourier-transform infrared spectroscopy). In this analysis, nineteen microplastic particles with different dimensions and shapes were recorded in sediment. Identification of structural groups in samples analyzed by FTIR-ATR shows that most of the particles are made of polyvinyl chloride, high-density polyethylene, and polyacetal. This research showed that microplastic is present in the surface sediment of the shelf and points out importance for further detailed studies and understanding of microplastic behavior and paths in the marine environments.

Keywords: *microplastic, shelf, sea bottom sediment, ATR, FTIR*

Giant Nummulites Maximus D' Archiac, 1850 from the Upper Lutetian (Eocene) Limestones of the Peri-Adriatic Littoral of Montenegro

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The Paleogene deposits of the littoral of Montenegro are as yet poorly known, except e.g. for the pioneering work of PAVIĆ (1970), although they are rich in larger benthic foraminifera (LBF). This area is very interesting because of the closeness of the Dinaridic thrust system and the contact of two major geotectonic units, Dinarides and Hellenides. The sedimentary successions deposited from the Cretaceous/Paleogene boundary onward record this complexity, punctuated by longer emergence phases in the early Eocene (Ypresian: Ilerdian). Later in Cuisian the shallow-water areas were surrounded by deeper-water environments, where clastic sedimentation took place, with breccias and conglomerates.

A major Lutetian transgression (SBZ 13) resulted in a shallow shelf in the subtropical zone and a warm and stable environment where nummulitids and discocyclinids thrived (HOHENEGGER, 2011). Such conditions still existed in the Bartonian (SBZ 17). This favorable environment suited K-strategists well and species diversification among nummulitids occurred (SCHAUB, 1981).

In 2019, we found a limestone near Grbalj with giant tests of *N. maximus* D'ARCHIAC, 1850 (SBZ 16- 17). This is rather rare species, that has been found in Dalmatia (Orebić, Pelješac peninsula; DROBNE & PAVLOVEC, 1988), Maiella Mt., the Tremiti islands and Gargano (SCHAUB, 1981). The diameter of the B form ranges from 9 to 11 cm and the thickness index is 13.3, i.e., the test is very flat; the measurements were performed on axial sections. The tests of the A forms are 6-9 times smaller. This species according to HOTTINGER (2001) reflects a Global Community Maturation.

The stratigraphical position of the species is constrained below by *N. millecaput* D'ARCHIAC, 1850, (SBZ 15, Lutetian), and above by abundant *N. perforatus* (DE MONTFORT), 1808 (SBZ 17, early Bartonian). Age attributions will be achieved by using also other LBF, planktonic foraminifers and nannoplankton, as well as by a comparison with the entire Adriatic region.

The aim of the present study is to correlate Paleogene LBF-bearing successions in Montenegro to Herzegovina, and further on to Friuli, Verona and the Lessini Mts. areas, applying the Shallow-Benthic Zonation (SBZ) (SERRA-KIEL et al., 1998, PAPAZZONI et al., 2017) and the biosedimentary zones, BiosZ 1-BiosZ 5 (DROBNE et al., 2009, 2017), to the whole Adriatic archipelago.

Keywords: *Nummulites maximus, upper Lutetian, Montenegro*

References

DROBNE, K. & PAVLOVEC, R. (1988): Velike foraminifere karbonatnega razvoja v paleogenu. INA NAFTAPLIN, Ljubljana, 35 p.

DROBNE, K., PAVŠIČ, J., HORVAT, A., OGORELEC, B. & PAVLOVEC, R. (2009): Cenozoic 6: part 6.1: Introduction to the Cenozoic, 6.2: Paleocene and Eocene in south-western Slovenia. In: PLENIČAR, M., OGORELEC, B. & NOVAK, M. (eds.): The Geology of Slovenia, GZS: 303-372.

DROBNE, K., TRUTIN, M., CELARC, B., ĆORIĆ, S., PREMEC-FUČEK, V., DOLENEC, M., LOJEN, S., HERNITZ-KUČENJAK, M & TARI, V. (2017): The role of Paleogene larger foraminifera and plankton in the subdivision of carbonate platforms on the Adriatic plate – the example of Herzegovina. In: 13. workshop on Alpine Geological Studies, Beograd, CD rom.

HOHENEGGER, J. (2011): Large foraminifera, greenhouse constructions and gardeners in the oceanic microcosm. The Kagoshima University Museum, Kagoshima, 81 p.

HOTTINGER, L. (2001): Learning from the past? In: LEVI-MONTALCINI, R. (ed.) Frontiers of Life 4/2: Discovery and spoliation of the Biosphere, Academic Press, London & San Diego, 440-477.

PAPAZZONI, C.A., ĆOSOVIĆ, V., BRIGUGLIO, A. & DROBNE, K. (2017): Towards a calibrated larger foraminifera biostratigraphic zonation: celebrating 18 years of the application of shallow benthic zones. Palaios, 32, 1-5.

References

PAVIĆ, A. (1970): Marinski paleogen Crne Gore, stratigrafija, tektonika, paleogeografija. Zavod za geološka istraživanja Crne Gore, Titograd, 205 p.

SCHAUB, H. (1981): Nummulites et Assilines de la Tèthys paléogène. Taxinomie, phylogénèse et biostratigraphie. Mémoires suisses de Paléontologie, Basel, 104-106, 238 p.

SERRA-KIEL, J. et 15 co-authors (1998): Larger foraminiferal biostratigraphy of the Tethyan Paleocene and Eocene. Bull. de la Soc.Geol. Fr., 169(2), 281-299.

Pull-Apart Basins of Southern Banat (Southeastern Part of the Pannonian Basin)

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In the Neogene complex of Southern Banat, several depressions of various size have been developed. They were classified, according to the conditions of forming, as a pull-apart type of the basin (AYDIN & NUR, 1982; ALAN & ALAN, 2013). Starting from the south to the north, the following basins are present: Drmno (maximum thickness of Neogene around 3900 m), Smederevo (2800 m), Zagajica (2800 m), Pančevo (3700 m), Plandište (2600 m) and Samoš (3600 m) – Figure 1. Base of these basins is made of Mesozoic formations of the Eastern Vardar Zone, Palaeozoic and Mesozoic formations of the Serbian-Macedonian Mass and the Palaeozoic Suprageticum formations. The Neogene sedimentation begins in the Lower Miocene, during which sedimentation is clastic (more or less molass type of sedimentation) and clastic carbonate sediments, with maximum thicknesses of about 1100 m, recorded in the Drmno de-

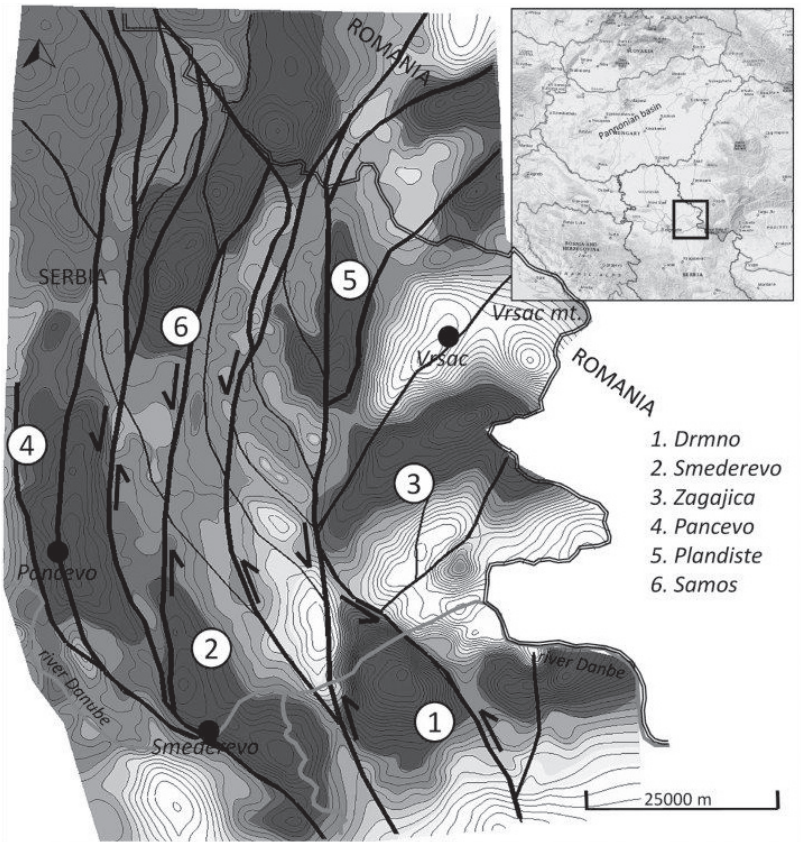

Figure 1. Map of the pull-apart basins of Southern Banat.

pression (HORVÁTH et al., 2018). Above are developed marine sediments of the Middle Miocene, represented by a clastic-carbonate and reef complexes, with maximum thickness of 1600 m, also recorded in the Drmno depression. In the lower part of the Upper Miocene, caspibrackish sediments are predominantly represented by clastic-carbonate sediments, with a maximum thickness of about 800 m. At the end of the Upper Miocene and the beginning of the Pliocene in the entire area of the southeastern part of the Pannonian Basin, a powerful progradation series (with thickness up to 1000 m) was developed, and led to the gradual filling of the pull-apart basin of Southern Banat.

Pull-apart basins of Southern Banat are located within the wide corridor of the Moravian Neogene strike-slip tectonic transformation and represent a part of the pull-apart basin chain developed in the South, along the Moravian Trench, and toward North and East, they extend to Romania. The width of the Moravian Transit Zone in South Banat is about 65 km and it has a dense network of longitudinal and transverse strike-slip faults. Pull-apart basins are formed by the stresses between the longitudinal regional faults, which are, as shown in the seismic image, at TWT of 8–9 ms, or up to Moho-discontinuity. Pull-apart basins are elongated, slightly arched and parallel with the position of main longitudinal folds, except Drmno basin which today have, more or less, spherical contour.

Seismic data indicate intensive Quaternary tectonic disturbance and deposition of sediments, and the seismic activity in this part of the Pannonian Basin and southern Carpathians confirm that the strike-slip tectonics of the Moravian corridor are still active today.

Despite the large amount of available 2D and 3D seismic, and geological data from a large number of deep wells, still remain open fundamental issues related to events happened during the Lower Miocene and development of pull-apart basin during the Sarmatian regional regression.

The prevailing opinion is that the existence of prominent young strike-slip systems can be more negative than a positive factor in migration, trapping and, in particular, the preservation of hydrocarbon accumulations.

However, the Southern Banat petroleum system is fully linked to relevant events, since the mature rocks were formed in pull-apart basins, and the migration of hydrocarbons and the formation of traps was made possible by a young strike-slip tectonics.

Keywords: *pull-apart, strike-slip, Southern Banat, Pannonian basin, Neogene*

References

ALAN, P. A. & ALAN, J.R. (2013): Basin Analysis: Principles and Application to Petroleum Play Assessment, 2013, John Wiley & Sons, Ltd., London, UK, 619.

AYDIN, A. & NUR, A. (1982): Evolution of pull-apart basins and their scale independence, Tectonics, 1, 91-105.

HORVÁTH, F., DULIĆ, I., VRANJKOVIĆ, A., KOROKNAI, B., TÓTH, T., WÓRUM, G. & KOVÁCS, G. (2018): Overview of geologic evolution and hydrocarbon generation of the Pannonian Basin, Interpretatien, doi:10.1190/INT-2017-0100.1

Modified Heavy Minerals Separation Procedure as a Tool in the Microplastics Analysis

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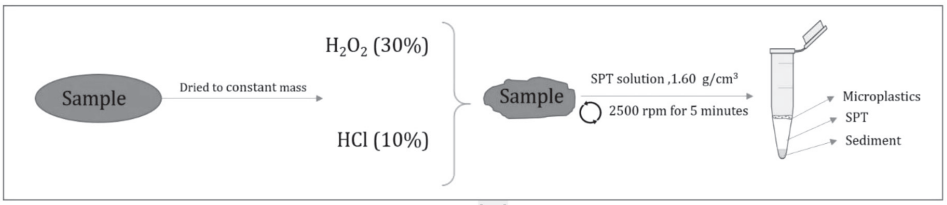
Microplastics (MP) can be defined as a plastic particle of size in the range from 0.5 to 5 mm, although there is an ongoing debate on the definition and the minimum size limit (CHUBARENKO et al., 2016). Plastics are synthetic organic polymers, which are derived from the polymerization of monomers extracted from oil or gas (COLE et al., 2011), with low density, in the range between 0.8-1.4 g cm^{-3}, as an important characteristic of MP. Sediment is one of the media where microplastics are present and therefore is regularly analyzed.

Analysis of microplastics can be divided into two main processes: separation of microplastics (a) and microplastics determination (b). Both of these steps have challenges and yet, there is no analytical procedure to follow but some recommendations. The most used process for microplastics separation from the sediment includes zinc chloride solution, and separation is based on different density of the microplastics and solution (LÖDER & GERDTS, 2015). Due to the toxicity of $ZnCl_2$ solution (ERGONUL et al., 2012), in our research, we modified heavy minerals separation procedure and successfully separated MP from sediment, with the chemical that can fit into the "Green Chemistry" philosophy. A known mass of homogenized and dry sediment is mixed with the sodium polytungstate



[A1]

Figure 1. Density separation of microplastics particles by SPT solution.

or SPT ($Na_6[H_2W_{12}O_{40}]$) solution of adjusted density at 1.60 g cm^{-3}. After stirring and centrifugation solution is frozen, to achieve better separation of particles with the lower density. Prior to the density separation, sediment samples are treated with the hydrogen peroxide (H_2O_2, 30%) to remove organic matter. This step is of great importance when biofouling is present, due to the density increase of particle of interest. One of the possible steps, depending on the mineralogy of the sample, is carbonate removal, with the hydrochloric acid (HCl, 10%). When small shells or tests are abundantly represented in the sample, this step is recommended. After MP separation is performed, particles are weighted to determine the amount of MP in sediment and ready for further determination by an instrument of choice (HIDALGO-RUZ et al., 2012).

Keywords: microplastics, sediment, SPT, density separation

References

CHUBARENKO, I., BAGAEV, A., ZOBKOV, M. & ESIUKOVA, E. (2016): On some physical and dynamical properties of microplastic particles in marine environment. Marine Pollution Bulletin, 108, 105-112.

COLE, M., LINDEQUE, P., HALSBAND, C. & GALLOWAY, T.S. (2011): Microplastics as contaminants in the marine environment: A review. Marine Pollution Bulletin, 62, 2588-2597.

ERGONUL, M., ATASAĞUN, S. & BEŞER, T. (2012): The acute toxicity of zinc chloride on Daphnia magna straus. Gazi University Journal of Science, 25, 313-316.

HIDALGO-RUZ, V., GUTOW, L., THOMPSON, R. C. & THIEL, M. (2012): Microplastics in the Marine Environment: A Review of the Methods Used for Identification and Quantification. Environmental Science & Technology, 46, 3060-3075.

LÖDER, M.G.J. & GERDTS, G. (2015): Methodology Used for the Detection and Identification of Microplastics – A Critical Appraisal. In: BERGMANN, M., GUTOW, L. & KLAGES, M. (eds.): Marine Anthropogenic Litter. Cham: Springer International Publishing, 201-227.

City Geoheritage – Geological and Geoturistical Aspect of the Natural Stone, Examples from Zagreb (Croatia)

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Natural stone is one of our main raw material products for domestic and various foreign markets. It is also a way to present natural heritage and geoheritage, especially, in our case, various sedimentary deposits, which cover most parts of Croatia. All of these varieties differ in colour and petrographic characteristics and are often rich in fossil remains.

As a part of the geotouristical offer, we can promote our geological knowledge not only to tourists but also to local people, schoolchildren, students, etc., as interesting facts about their city and culture. The city of Zagreb, especially its central part, exhibits various types of natural stone, which are often domestic, or from near-by areas. The main role of the stone built into a construction is to be protective, durable and decorative. Some of the main Croatian varieties of stones that can be seen on the streets and as building material include sedimentary rocks as *Lithothamnium* limestones and "Litavac", various types of rudist limestones – with fragments or complete rudist bivalves, stilolitic limestones, oncolytic limestones, *Lithiotis* limestones etc.

The main building material in Zagreb includes *Lithothamnium* limestone and "Litavac", calcareous rudstones composed mainly of fragments of coralline algae, from local Bizek and Gornje Vrapče quarries. Many famous buildings (or their parts) were built from these varieties throughout our history, with the Cathedral being the most known. Unfortunately, due to the composition of the stone and its high porosity, these varieties are commonly susceptible to chemical weathering and mechanical damage, and often replaced.

Rudist limestones include different varieties, with the most known white coloured Veselje unito, often wrongly named "Brač marble". It is used as building material for different sacral and historical buildings in Croatia and neighbouring countries, including the Croatian National Bank and Croatian Association of Artists building.

Stilolitic limestone, also named Kirmenjak or Pietra d'Istria, is stone of highest quality in Croatia, whose decorative criteria is pronounced when blocks are sawed perpendicular to the layers. Its durability and resistance to weathering are certified by its historical use as a building stone in Venice, where it is constantly exposed to seawater.

Magmatic and metamorphic rock varieties are not common as natural stones in Croatia and are therefore mainly imported. Varieties of silicate composition are firmer and more resistant to abrasion, more durable and absorb less water compared to sedimentary rocks. Therefore, different varieties of granites (e.g., Liberecká žula from Czech Republic, Rossa Porrino from Spain), trachytes (e.g., Peperino Rosso cubes from Italy) and gabbros (e.g., Jablanica Tamni from Bosnia and Herzegovina) have been used for pavements and parts of the monuments on the main squares and streets in the Zagreb centre.

Natural stones can represent a part of a geotouristical offer for any place or region. Information and knowledge concerning certain rock types, their geological age and origin, as well as exploitation methods and their possible usage can give an overview on their importance and preservation as part of cultural heritage and geoheritage.

Keywords: *natural stones, geoheritage, geotourism, Zagreb, Croatia*

Environmental Stress within Lower Triassic Clastic and Carbonate Deposits (Muć–Ogorje, Central Dalmatia)

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Lower Triassic clastic and carbonate deposits are well exposed and known in the area of Muć (HERAK et al., 1983), enabling detailed interpretations concerning the depositional environment and changes throughout a 270 m thick succession exposed along the road Muć–Ogorje in Central Dalmatia. The succession comprises mainly reddish clastic deposits in its lower part and yellowish-grey carbonate deposits in the upper part. Detailed logging revealed that clastics and carbonates are often interchanging in the upper part of the succession, giving new clues on the depositional conditions. Clastic deposits are commonly micaceous, vary in size from siltstones to medium-grained sandstones and are attributed to deposition in an offshore transition environment, as attested by the occurrence of storm deposits (Fig. 1A) and slumps (Fig. 1B). Similar deposits were reported about 50 km away in the vicinity of Knin (ALJINOVIĆ, 1995; ALJINOVIĆ et al., 2018), thus suggesting that a broad shelf occupied this area during the Early Triassic.

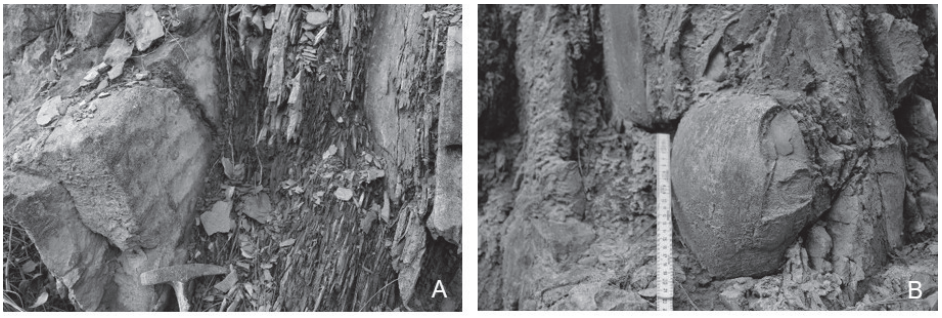

Figure 1. A. Ripple marks on the upper bedding plane of a sandstone bed, interpreted as storm deposits. Finely laminated siltstones are interpreted as background sedimentation during fair weather conditions; B. Slumps or possible storm depositional structures.

Fossil findings within the clastic lower part are rare, mainly internal and external moulds of bivalve shells (*Unionites*). In the carbonate part of the succession, fossil findings include common gastropod remains (*Werfenella*) and visible bioturbation, with sporadic occurrence of ammonites (*Tirolites*) (VUDRAG & SREMAC, 2015; this study).

Variations in lithology, colour of deposits and fossil content throughout the succession suggest frequent changes in depositional conditions. Siliciclastic deposits in the lower part of the succession comprise only bivalves, indicating modest macrofossil recovery, while carbonates in the upper part contain a more diverse fossil community, including gastropods, rare bivalves and ammonites. Carbonate deposits are thought to reflect tectonically driven episodes of basin deepening, whereby the reduction of siliciclastic input generated favourable conditions for biota. However, siltstone intercalations are barren of any visible fossils, suggesting that siliciclastic input negatively affected present biota leading to enhanced stress in already stressed environment in the aftermath of the end-Permian extinction.

Keywords: *Lower Triassic, Ogorje, clastics, carbonates, storm deposits*

References

ALJINOVIĆ, D. (1995): Storm Influenced Shelf Sedimentation – An Example from the Lower Triassic (Scythian) Siliciclastic and Carbonate Succession near Knin (Southern Croatia and Western Bosnia and Herzegovina). Geologia Croatica, 48/1, 17-32.

ALJINOVIĆ, D., HORACEK, M., KRYSTYN, L., RICHOZ, S., KOLAR-JURKOVŠEK, T., SMIRČIĆ, D. & JURKOVŠEK, B. (2018): Western Tethyan epeiric ramp setting in the Early Triassic: an example from the Central Dinarides (Croatia). Journal of Earth Science, 29, 4, 806-823.

HERAK, M., ŠĆAVNIČAR, B., ŠUŠNJARA, A., ĐURĐANOVIĆ, Ž., KRYSTYN, L. & GRUBER, B. (1983): The Lower Triassic of Mud – Proposal for a standard section of the European Upper Scythian. Österreichische Akademie der Wissenschaften, Schriftenreiche der Erwissenschaftlichen Kommissionen, 5, 93-106.

VUDRAG, M. & SREMAC, J. (2015): Early Triassic deposits of Ogorje (vicinity of Mud). In: MAUCH LENARDIĆ, J., HERNITZ KUČENJAK, M., PREMEC FUĆEK, V. & SREMAC, J. (eds.): International scientific meeting 100th birth anniversary of Vanda Kochansky-Devidé, Zagreb. Abstracts. HAZU, 82-83.

Comparison of Photogrammetry Models Obtained by Various Image Acquisition Techniques on Šterna Badland in Istria

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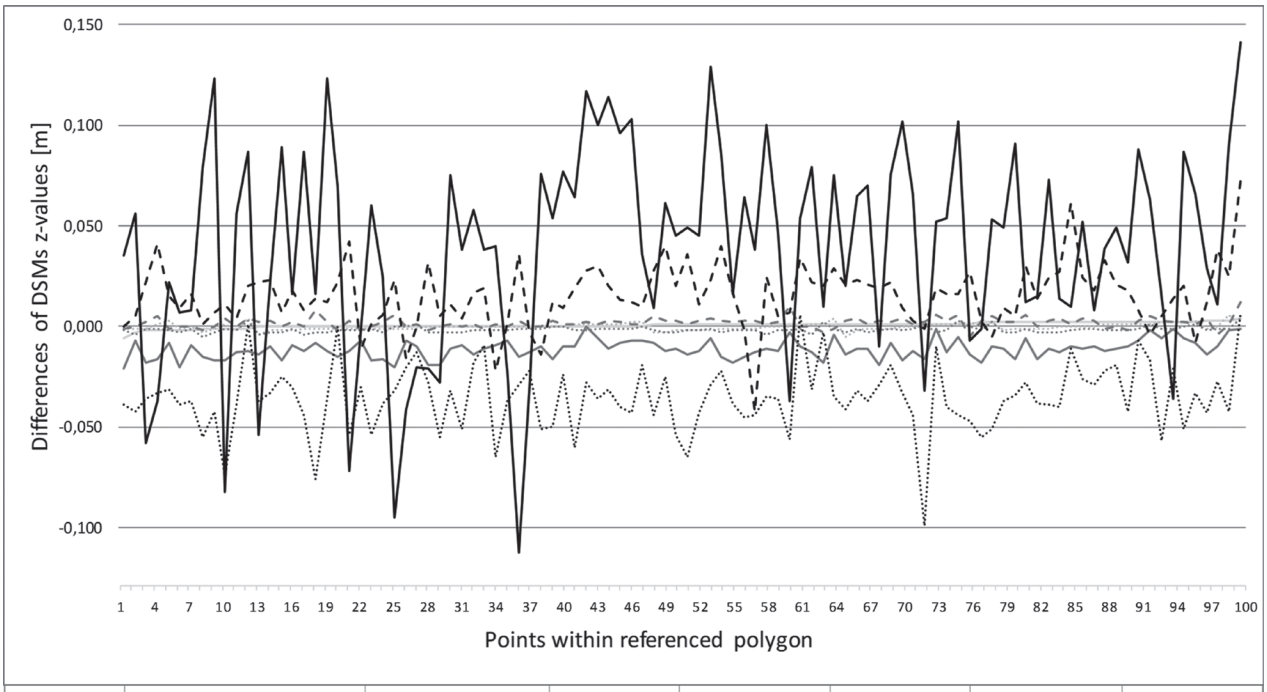
Badlands in Istria present specific isolated relief units characterised by extremely dissected landscape with minimal or none vegetation cover and high drainage density. They are the consequence of intense erosion processes in the area with highly erodible flysh deposits, which are mainly composed of sandstone and marl layers (GULAM, 2012). To understand the dynamics of badland denudation and quantify temporal changes, it is necessary to get the exact measures of their morphology. In that sense, the use of photogrammetry proved to be a good tool for badland 3D model creation (STÖCKER et al., 2015; GULAM et al., 2018). As the photogrammetry is based on taking multiple overlapping photographs, different image acquisition techniques are tested and presented in this work. The test polygon is established on Šterna badland in Istria, covering app. 37.000 m^2. Within, for close range photogrammetry, several smaller pilot polygons are defined, with an area of several square meters.

Several image acquisition techniques were used to obtain photogrammetry models, including two different methods, airborne and terrestrial (Fig. 1). For airborne image acquisition different UAV (unmanned aerial vehicle) types were used, fixed-wing (senseFly eBee and Topcon Sirius Pro) and multicopter UAVs (senseFly Albris and Falcon 8+ Topcon Edition). The flights were performed at different altitudes combining automated, semi-automated and manual flight modes. Ground-based images were taken using DSLR camera (Nikon D610 with 35 mm f/2 lens) with and without the tripod, and mobile phone camera (Huawei P8 Light).

The images were processed with Pix4Dmapper software aimed to get high-resolution 3D models. Ground control points (GCP) were used for improving model positioning



Symbol	Image acquisition techniques	Flight / Photo mode	Flight height [m]	Area covered [m²]	Images calibrated for model	Number of ground control points	Ground sample distance [cm]
——	senseFly eBee	automated	170	746747.50	176	15	4.74
- - -	senseFly eBee	automated	106	805621.14	479	15	3.00
·····	Topcon Sirius Pro	automated	100-120	477213.06	433	14	2.55
- - -	Falcon 8+ Topcon Edition	manual	11-16	413.91	40	5	0.19
——	senseFly albris	automated	11.5	11603.37	356	10	0.33
·····	senseFly albris	semi-automated	4	413.34	265	10	0.07
·····	DSLR (Nikon D610)	hand held	-	187.93	23	5	0.07
——	Huawei P8 Lite	hand held	-	19.91	16	5	0.10
Ref. model	DSLR (Nikon D610)	with tripod	-	10.11	5	5	0.07

Figure 1. The comparison of DSMs processed using different image acquisition techniques.

and accuracy. Fifteen black and white markers were placed over the investigated area for UAVs high altitude-flights, and metal bolts were drilled into the rock on smaller pilot polygons for UAVs low-altitude flights, app. five bolts per polygon. This allowed the GCPs recognition on the images captured. Overall, 109 GCPs were set within investigated area. Their positions were precisely measured on the field with a total station (Leica TCR 705).

To test the difference of digital surface models (DSMs) obtained by different image acquisition techniques, a preliminary analysis was performed in GIS environment. For that purpose, all DSMs that were processed for one pilot polygon were compared. The cell values (Z coordinate) of DSMs were extracted for 100 points randomly created within the polygon of 7.45 m^2 and compared. DSM obtained from images acquired by DSLR camera with tripod was taken as the reference model.

The first results of DSMs comparison are shown for all image acquisition techniques (Fig. 1). Logically, the biggest aberrations from reference model are recorded for the highest UAV flight (eBee on 170 m), ranging from -0.112 to 0.141 m. By reducing the height of the flight, deviations from the reference model are significantly decreased. The same trend can be seen for Albris UAV. Decreasing the flight height from 11.5 to 4 m, ground sampling distance (GSD) decreases from 0.33 to 0.07 cm. This improves the model, but data collection requires more effort, since the flight mode is changed to semi-automated (manual flight with locked distance from the ground).

Comparing the DSMs obtained by images captured with Falcon 8+ and Albris, the one processed using Falcon 8+ images showed much better results due to size and quality of camera sensor, although the camera resolution is similar (~40 MP). The quality and dynamic range of photos produced by Sony A7r camera which is used by Falcon 8+ proved much bigger influence on overall model quality then superior flight planning software used by Albris. While Falcon 8+ flies at constant height (future updates

of mission planning software might change that), Albris follows the terrain morphology when flying.

Using the terrestrial image acquisition techniques (DSLR and mobile phone camera) much smaller areas can be covered, but their DSMs show negligible differences. Thus, the use of mobile phone camera for photogrammetric models should be tested in more detail.

Further research will be focused on choosing the optimal method for image acquisition in badland areas, aimed to get photogrammetry 3D models accurate enough to map morphological details and monitor denudation rates, which for Istrian badlands ranges between 0.5 and 5.5 cm per year (GULAM, 2012).

Keywords: *photogrammetry, 3D model, badland, denudation, UAV*

References

GULAM, V. (2012): Erozija ogolina u flišu središnje Istre [The erosion of flysch badlands in the Central Istria – in Croatian, with an English Abstract]. Unpubl. PhD Thesis, Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, 275 p.

GULAM, V., GAJSKI, D. & PODOLSZKI, L. (2018): Photogrammetric measurement methods of the gully rock wall retreat in Istrian badlands. Catena, 160, 298-309.

STÖCKER, C., ELTNER, A. & KARRASCH, P. (2015): Measuring gullies by synergetic application of UAV and close range photogrammetry – A case study from Andalusia, Spain. Catena, 132, 1-11.

Geological Cross-Sections of the Wider Area of Rijeka – Project GEOSEKVA

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Within the HRZZ research project: GEOSEKVA (Geological and Seismological aspects of Geodynamics in Kvarner area – unveiling of the Kvarner fault) during the first two years (2017 and 2018) detailed geological investigations of the wider area of the Rijeka were conducted (Fig. 1A). One of the main goals of the project is construction of new and more reliable 3D geological models of selected structures within the Kvarner area. Presented geological cross-sections (Fig. 1B) are the first results of the research. As a base for achieving the main research objectives of this part of the project, it is necessary to create a new geological (lithostratigraphic) map of the selected zones (profiles) in scale 1: 25,000, and to construct geological cross-sections through selected structures in Rijeka area. Except the wider area of the Rijeka, systematic geological research within the GEOSEKVA project are carried out on the Labin peninsula and in the wider area of the Učka mountain.

In Rijeka area, we defined 16 informal lithostratigraphic units presented on geological maps and cross-sections: TIT (Tithonian limestone), DR (Dragozetići formation), CR (Cres formation), KA (Kanfanar formation), PO (Porozina formation), CN (Crna formation), SIS (Sis formation), MI (Milna formation), SD (Sv. Duh formation), BS (Basina formation), GH (Gornji Humac formation), KKV (crystalline limestone), FV (Foraminiferal limestones), FL (Flysch), Qgfl (Quaternary glacial-fluvial deposits) and Q (Quaternary, in general). Most of the lithostratigraphic units are defined and presented on the published sheets of Basic Geological Map of the Republic of the Croatia in 1: 50,000 scale of the neighbouring islands of Cres and Lošinj (FUČEK et al., 2015). The stratigraphic range of the lithostratigraphic units is from the Upper Tithonian to the Quaternary. Total thickness of deposits is estimated between 3200 and 4000 meters. Geological cross-sections presented in Fig. 1B indicate complex tectonics of this area also inferred from strongly fractured carbonates in the Rijeka area. Steep faults characterized by Dinaridic NW-SE strike with horizontal (mostly right-lateral) movements predominate, dissecting partly reactivated older Dinaridic thrust faults. However, there are also faults transversal to the strike of Dinaridic structures. All profiles end up in the northeastern part within the the great anticlinal structure of Gorski Kotar. To characterize the contact between this anticline structure with the complex structure of Grobnik-Obruč is still our primary objective for further research.

Acknowledgements

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Keywords: *lithostratigraphic units, geological cross-section, wider area of Rijeka*

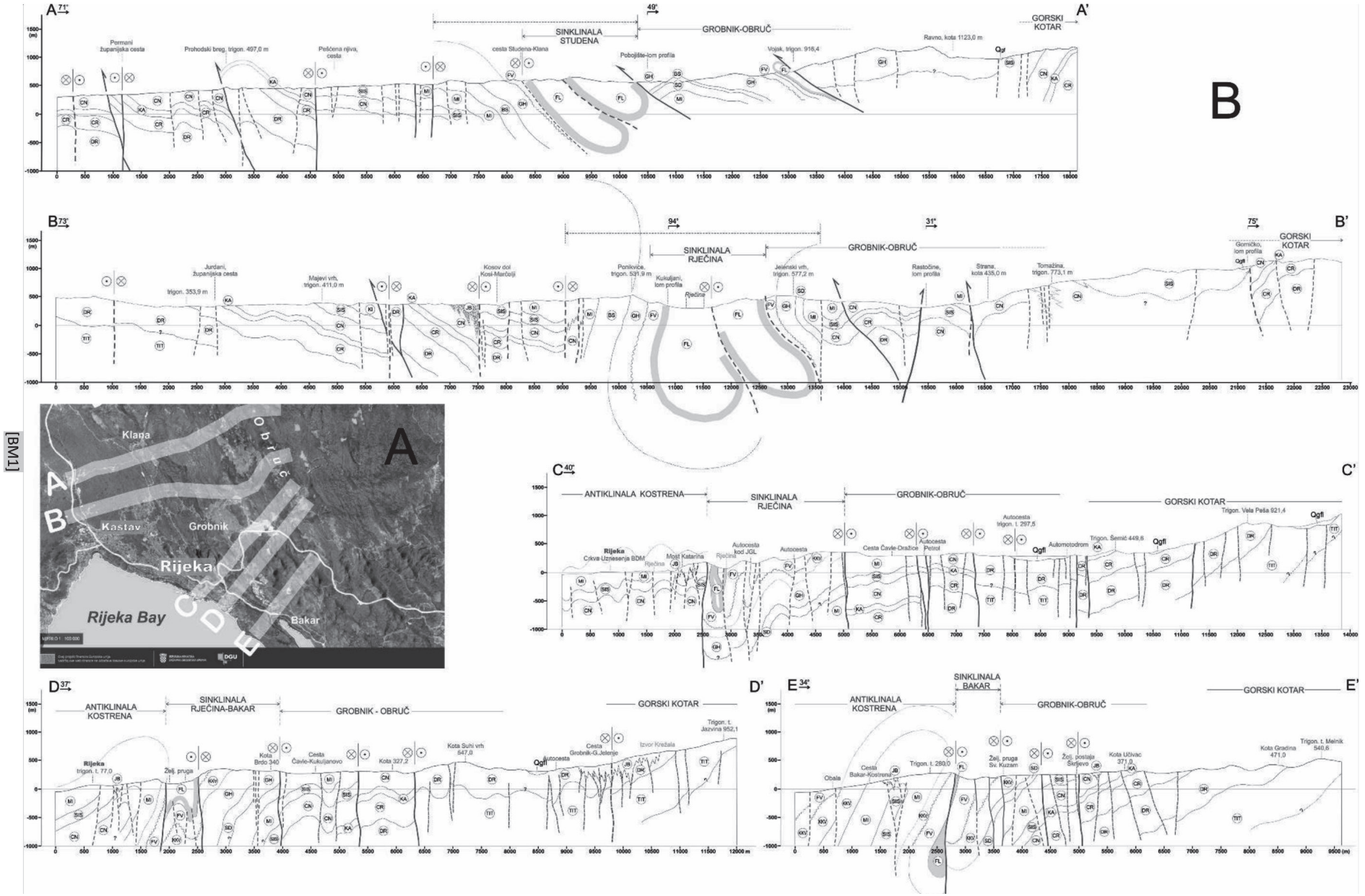

Figure 1. A) Location of selected geological mapping profiles. Source map:https://geoportal.dgu.hr/ , and B) geological cross-sections of mapping profiles.

References

FUČEK, L., MATIČEC, D., VLAHOVIĆ, I., OŠTRIĆ, N., PRTOLJAN, B., KOROLIJA, B., KORBAR, T., HUSINEC, A. & PALENIK, D. (2015): Osnovna geološka karta Republike Hrvatske mjerila 1:50 000 – list Cres i Lošinj [Basic Geological Map of the Repulic of the Croatia 1:50,000 Scale – Cres and Lošinj sheet]. Hrvatski geološki institut, Zavod za geologiju, ISBN: 978-953-6907-53-3, Zagreb.

Palaeoecology and Climate Change during the Karpatian/ Badenian Transition in Conjunction with Local to Global Events

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Miocene sediments from the Medvednica Mt. belong to the North Croatian Basin of SW Central Paratethys. The marine succession of the Karpatian/Badenian transition near Čučerje village and from nearby outcrops at Bokanjščica stream, expose ca. 90 m thick marly deposits with intercalations of clastic sediments containing rich and very well preserved microfaunal assemblages (planktonic and benthic foraminifera, ostracods) with calcareous nannofossil.

Karpatian

The last appearance of *Helicosphaera ampliaperta* BRAMLETTE & WILCOXON is noticed where *Sphenolithus heteromorphus* DEFLANDRE Paracme ends and represents a very useful correlation tool defining the Subzone MNN4b (MNN4c recently) within Chron C5Br in Langhian successions of the Mediterranean estimated at 15.527 Ma. This zone is correlated with the NN4 Zone in Karpatian successions of the Paratethys.

The basal part of the interval is characterised by the domination of smaller to medium coccoliths of *Coccolithus pelagicus* (WALLICH) SCHILLER, typical for cold, eutrophic waters. *Helicosphaera carteri* (WALLICH) KAMPTNER flux could be a consequence of lower surface temperatures (ca. 15 °C). Similar abundances of *H. carteri* are associated with today's known La Niña episodes in the tropics while it has been recognized here during the MCO (ca. 17-15 Ma). Nevertheless, planktonic foraminiferal assemblage consists of numerous specimens of the cool surface water indicators such as *Tenuitella munda* (JENKINS), *Tenuitella angustiumbilicata* (BOLLI) and *Globigerinita glutinata* (EGGER). This fits well with already noticed larger climate instability during the early stage of the MCO. An increase in Si component was likely a direct effect of the cooler temperatures favouring siliceous organisms during the long-term global climate cooling (Mi2 event) at ca. 16 Ma. This is evident especially in the upper part of interval, where silicoflagellate, diatom and radiolarians implying to intensified upwelling caused by a shift in the local current system during the global cooling. Nevertheless, larger temperate forms of *C. pelagicus,* known from upwelling regions where temperature ranges from 13-16 °C, dominates in assemblage. However, skeletons of siliceous organisms are mostly broken probably because of the unstable shallower environment of coastal turbulent, nutrient enriched water. It is detected in assemblage with abundant *Pontosphaera multipora* (KAMPTNER, ex DEFLANDRE in DEFLANDRE & FERT) ROTH, which is indicative for the shallow marine nearshore environment with normal to slightly hyposaline water due to the seasonally driven convergence of different water bodies. Frequent occurrence of benthic foraminiferal infaunal genera *Bolivina*, *Bulimina* and *Melonis* indicate a low oxygen but organic carbon reach sea bottom.

Badenian

The regular occurrence of coccolith *S. heteromorphus* together with close records of *Helicosphaera waltrans* THEODORIDIS corresponding to the Mediterranean Subzone MNN5a. In the Paratethys, it is detected in the lower part of the *Helicosphaera waltrans* horizon of early Badenian.

In early Badenian small *Reticulofenestra* species dominates in assemblage with abundant *H. carteri*, common *Reticulofenestra haqii* BACKMAN and sphenoliths. Similar nannoflora assemblage is recorded in Messinian, in shallow, hypersaline environment with periodic influxes of fresh, nutrient rich water. This resulted in an extreme environment with highly fluctuating salinity levels and elevated abundances of *Reticulofenestra minuta* ROTH. The

increasement of *C. pelagicus* was also noticed probably as a result of the aforementioned convergence of different water bodies. Planktonic foraminiferal association is characterised by prevailens of warm water *Cassigerinella chipolensis* (CUSHMAN & PONTON) (50%) over cool water *Turborotalita quinqueloba* (NATLAND) (10%). Warmer climate and MCO was reestablished in the early Badenian but in more fluctuating environment. Discovery of very rare Indo-Pacific ostracod *Paijenborchella iocosa* KINGMA indicates the establishment of connections between the Paratethys, Mediterranean and Indo-Pacific Ocean. This is in accordance with the Badenian transgression that began at 15.4 Ma and recognised above the Lan2/Ser1 sequence boundary. Reach and highly diversified benthic foraminiferal assemblage, dominated by infaunal organic carbon-preferring genera such as *Bulimina*, and low-oxygen adapted taxa like *Bolivina*, *Uvigerina* and *Pappina,* indicate middle shelf environment where *Bolivina* dominates, while relatively abundant dinocyst association (*Systematophora placacantha* (DEFLANDRE & COOKSON) DAVEY et al., *Lingulodinium machaerophorum* (DEFLANDRE & COOKSON) WALL, *Melitasphaeridium choanophorum* (DEFLANDRE & COOKSON) HARLAND & HILL, *Spiniferites* sp., *Lejeunacysta* sp.) indicate somewhat deeper and distal marine environment.

Keywords: microfossils, Karpatian/Badenian transition, SW Central Paratethys

The Age of the Đurđevac Sands

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The Alpine orogenesis resulted in intense erosion of the elevated mountains and gravitational transport of the material. During the Pleistocene glaciation, an increase in the volume of ice resulted in intense crushing and grinding of rocks. During interstadials, the ice was melted and the grained material was transported and additionally fragmented by newly formed rivers (as the Drava River) to lowlands and formed floodplains. A lot of material in suspension and reduction of the potential energy of the flow caused meander development and periodical floods followed by deposition of fine-grained sediments in the Podravina region. Also, during the cooling periods and freezing of the vegetation, the northwest winds blew away silty and clayey material. These natural separation processes resulted in accumulation of medium-sorted sand with a high percentage of heavy mineral fraction (HMF) (7-54%) (GALOVIĆ & POSILOVIĆ, 2017). Light mineral fraction (LMF) is dominated by quartz and HMF by garnet (GALOVIĆ & POSILOVIĆ, 2017).

Based on HEĆIMOVIĆ (1987), during the Holocene this sands have been repeatedly resedimented by winds and formed dunes (the Đurđevac Sands) that are discordantly situated on the Pleistocene loess of the Bilogora Mt. slopes, and in the Drava River Valley on the Holocene sands and gravels of the second alluvial terrace and partly on the marshy sediments. Mineral composition of sands and transport by saltation mechanism disabled preservation of potential fossils. Based on Mohs scale of mineral hardness, the sand grains are almost exclusively harder (>6) than calcite/aragonite mollusc shells and dentin (3) or even tooth enamel (5). Thus the age of the Đurđevac Sands was determined by the superposition principle.

During dry years, the sand was unsuitable for rooting. In history, the Đurđevac Sands were a real threat to agricultural cultures and settlements in this area due to their instability. Settling of sands at the end of the 19th and early 20th centuries was achieved, mainly by afforestation. Recent forest arenosol has an organic horizon (O_h) 1-3 cm thick and a humus horizon (A_h) up to 10 cm. At control sites, without affecting forest vegetation, arenosol is low in humus (up to 2 cm) (VRBEK et al., 2017). Generally, arenosols are typical soils developed on recent dunes from arid to humid and per humid, and from extremely cold to extremely hot climate. The vegetation ranges from a desert over scattered vegetation (mostly grassy) to light forest (IUSS WORKING GROUP WRB, 2015).

The climate in the area is continental, with springs warmer than autumns. According to Lang's rainfall factor, the area of the Đurđevac Sands, during the reference period 1961-1990 had humid, and during the modern period 1991-1996 semi-humid climate, indicating climate warming (BILANDŽIJA et al., 2017).

Within the CSF project SAPIQ, in 2016 the Đurđevac Sands were preliminarily investigated in the sandpit Draganci. Within the sand dunes sets, two palaeosoils, type arenosol, were discovered (Fig. 1). Sedimentological analysis and sampling of palaeosoils and overlying and underlying sands were performed. It was intended to correlate the Holocene warm humid periods documented by pedogenesis (charcoal pieces extracted from the palaeosoils dated by

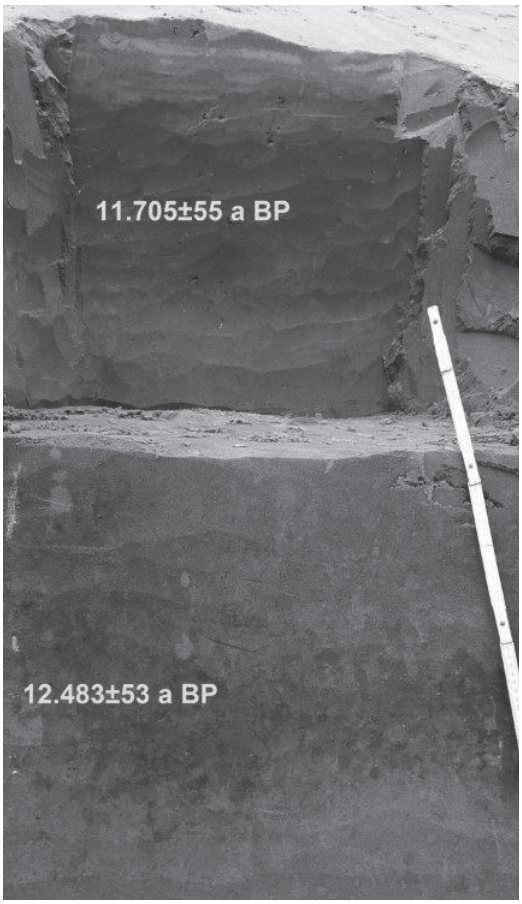

Figure 1. Two palaeosoils (arenosol), revealed within sand dune sets of the Đurđevački Sands. Different degree of pedogenic development indicates different climate optimums. Charcoals from palaeosoils are dated by ^{14}C method.

the ^{14}C method) with the historical data during which the dunes did not travel.

Unexpectedly, the analysis showed that these two palaeosoils developed just before and at the very beginning of the Holocene. Preserved bioturbations confirm that the palaeosoils are in situ. The older palaeosoil (12.483±53 a BP) is the thinner (about 15 cm thick) and the degree of pedogenic development indicates semi-arid climate with annual rainfall less than 300 mm and predominantly covered by grass (IUSS WORKING GROUP WRB, 2015; PEYRAT, 2007). It is similar to the modern forest soil in the area. The younger palaeosoil (11.705±55 a BP) is about 40 cm thick and pedogenetically well-developed. The upper border is erosional, so the original thickness cannot be assumed. However, it can be assumed that the climate was warmer and more humid, vegetation lusher than today and/or it can be assumed that this pedogenesis lasted longer. A lamination of sands underlying those palaeosoils is not noticeable. However, 20 meters laterally, the metric sets of the dune laminas beneath the palaeosoils were recognised. Based on superposition, it can be concluded that those dune laminas are older than dated palaeosoils, and were formed by the end of the Pleistocene. During that dry and cold period, the Drava River has provided enough sandy material (HEĆIMOVIĆ, 1987) and aeolian resedimentation could form the dunes.

Thus, it is possible that older dune sediments of the Đurđevac Sands were formed before the end of the Pleistocene, and palaeosoils formed just before and at the beginning of the Holocene preserved them from erosion.

Keywords: *Đurđevac Sands, palaeosoil, dune, Holocene, Pleistocene*

References

BILANDŽIJA, D., BAŠIĆ, F., KISIĆ, I., MESIĆ, M., ZGORELEC, Ž., ŠESTAK, I., PERČIN, A. & BOGUNOVIĆ, I. (2017): Agroklimat-ski pokazatelji kao indikator klimatskih promjena na Đurđevačkim pijescima. In: BAŠIĆ, F. & FELETAR, D. (eds.): Zbornik sažetaka Znanstvenog skupa Đurđevački pijesci - geneza, stanje i perspektive, Đurđevac, 29.-30.6.2017. Zagreb: Hrvatska akademija znanosti i umjetnosti: Zavod za znanstvenoistraživački i umjetnički rad Koprivničko-križevačke županije u Križevcima, 9.

GALOVIĆ, L. & POSILOVIĆ, H. (2017): Geneza i značenje eolskih naslaga Podravine. In: BAŠIĆ, F. & FELETAR, D. (eds.): Zbornik sažetaka Znanstvenog skupa Đurđevački pijesci - geneza, stanje i perspektive, Đurđevac, 29.-30.6.2017. Zagreb: Hrvatska akademija znanosti i umjetnosti: Zavod za znanstvenoistraživački i umjetnički rad Koprivničko-križevačke županije u Križevcima, 3.

HEĆIMOVIĆ, I. (1987). Osnovna geološka karta SFRJ 1:100.000. Tumač za list Đurđevac L33–71 [Basic Geological Map of SFRY, scale 1:100.000, Guidebook of the geological map for the Đurđevac sheet – in Croatian]. Belgrade: Federal Geological Survey, 39 p.

IUSS WORKING GROUP WRB (2015): World Reference Base for Soil Resources 2014, update 2015 International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Reports No. 106. FAO, Rome, 192.

PEYRAT, J. (2007): Development, properties and classification of dune soils in the Curonian Spit National Park, Russian part. Geologija, 59, 59-64.

VRBEK, B., PERNAR, N., BAKŠIĆ, D. & PERKOVIĆ, I. (2017): Neke pedološke značajke ekosustava Đurđevačkih pijesaka. In: BAŠIĆ, F. & FELETAR, D. (eds.): Zbornik sažetaka Znanstvenog skupa Đurđevački pijesci – geneza, stanje i perspektive, Đurđevac, 29.-30.6.2017. Zagreb: Hrvatska akademija znanosti i umjetnosti: Zavod za znanstvenoistraživački i umjetnički rad Koprivničko-križevačke županije u Križevcima, 8.

Geochemistry and Hydrocarbon Potential of the La Luna Formation in the El Salto Section, Middle Magdalena Valley Basin – Colombia

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The La Luna Formation is a calcareous monotonous sequence composing of organic-rich black shales and limestones whit discoidal concretions. It was deposited in a deep-water marine environment with restricting oxygen in the sea floor. This formation has been considered by ZUMBERGE (1984) and RANGEL et al. (1996) as the most important hydrocarbon source rock in the Middle Magdalena Valley Basin in Colombia, as well as in the Maracaibo Basin in Venezuela (TALUKDAR et al., 1986). This work analyzes The La Luna formation rocks using organic and inorganic geochemical techniques.

X-ray fluorescence is an easy, accurate and fast tool to chemically analyze the composition of rocks without previous preparation (LARRIESTRA, 2011; LARRIESTRA & MERINO, 2014; NAWRATIL et al., 2012). A detailed geochemical study was performed on the rocks deposited from the Turonian to the Cenomanian, known as La Luna Formation, in an outcrop of the El Salto creek to the north of the Middle Magdalena Valley basin (MMV), Colombia. The purpose was to evaluate by X-ray Fluorescence the elemental variability related to environmental changes occurred during depositional processes and investigate the possible relationship between inorganic and organic geochemical data. The element concentrations of Rb, Cs, Zr, Ce, La, Be and Th and oxide concentrations Al_2O_3, SiO_2, Fe_3O, K_2O, CaO, P_2O_5 indicate the rocks from La Luna Formation carry an important sediment supply from detrital origin; in turn off, the Al/(Al+Fe+Mn)= 0,79 indicate these rocks have not been altered by hydrothermal processes. Further, Al_2O_3 vs TiO_2 indicate the detrital contribution came from a constant source (ROSS & BUSTIN, 2008). Trace metals like V, Cr, U, Th, Mo and Re can be related with increased organic paleo-productivity indicators (ROSS & BUSTIN, 2009; SAGEMAN et al., 2003). Trace elements such as U, Ni, V and Cr indicated that the paleo-environmental conditions during deposition of La Luna Formation were poor in oxygen, changing from the dysoxic to the anoxic stage.

Through conventional organic geochemistry, according to the PETERS & CASSA (1994) classification scale, the parameters to evaluate the hydrocarbon generation potential of the rocks (Quantity, Quality and the thermal maturity state of organic matter) were established. The average TOC data in La Luna formation were 3.28 %w indicating that this section contains highly valuable organic matter content. In average HI values are 468 mg HC/g TOC which correspond to amorphous marine, type II organic matter (oil prone). The S_2 average is 15.76 mg HC/g of rock, it indicates the potential to generate hydrocarbons is very good. Furthermore, Tmax values (in average = 436 °C) indicate an early stage of hydrocarbon generation (early oil window). The organic geochemistry data suggest that the La Luna Formation is a hydrocarbon source rock with very good potential to generate oil.

This case study demonstrates that data from performed X-ray fluorescence analysis and conventional organic geochemistry can be used to accurately define stratigraphic intervals with optimal conditions for the preservation of organic matter, which are, in turn, essential for the generation of hydrocarbons.

Keywords: La Luna Formation, Middle Magdalena Basin, geochemistry, hydrocarbons, X-ray fluorescence, El Salto Section

References

LARRIESTRA, C. (2011): Soft Inorganic Geochemistry: A New Concept for Unconventional Resources Modeling, 80311.

LARRIESTRA, C. & MERINO, R. (2014): High resolution non-destructive chemostratigraphy of Vaca Muerta Formation, Argentina: new evidence of black shale sedimentary features. AAPG Search and Discovery Article #41310. AAPG Annual Convention and Exhibition, Houston TX., 41310.

NAWRATIL, A., GOMEZ, H. & LARRIESTRA, C. (2012): Key Tools for Black Shale Evaluation: Geostatistics and Inorganic Geochemistry Applied to Vaca Muerta Formation, Neuquen Basin, Argentina*. AAPG International Conference and Exhibition, 41028, 19.

PETERS, K.E. & CASSA, M.R. (1994): Applied source rock geochemistry. En L. B. MAGOON & W. G. DOW (eds.): The petroleum system – from source to trap: Memoir, 60, (93-120). American Association of Petroleum Geologists.

RANGEL, A., GIRALDO, B., MAGOON, L., SARMIENTO, L.F., BARTELS, H., MORA, C., CORDOBA, F., LUNA, O. & REYES, J.P. (1996): Oil potential of the Cretacic megasequence and associated oil families in the Middle Magdalena Valley, Colombia. Proceedings of the 5th Latin American Congress on Organic Geochemistry, Cancún, México. Vol. 105.

ROSS, D.J.K. & BUSTIN, R.M. (2008): Characterizing the shale gas resource potential of Devonian-Mississippian strata in the Western Canada sedimentary basin: Application of an integrated formation evaluation. AAPG Bulletin, 92(1), 87-125. https://doi.org/10.1306/09040707048

References

ROSS, D.J.K. & BUSTIN, R.M. (2009): Investigating the use of sedimentary geochemical proxies for paleoenvironment interpretation of thermally mature organic-rich strata: Examples from the Devonian-Mississippian shales, Western Canadian Sedimentary Basin. Chemical Geology, 260(1-2), 1-19. https://doi.org/10.1016/j.chemgeo.2008.10.027

SAGEMAN, B.B., MURPHY, A.E., WERNE, J.P., VER STRAETEN, C.A., HOLLANDER, D.J. & LYONS, T. W. (2003): A tale of shales: The relative roles of production, decomposition, and dilution in the accumulation of organic-rich strata, Middle-Upper Devonian, Appalachian basin. Chemical Geology, 195(1-4), 229-273.

TALUKDAR, S., GALLANGO, O. & CHIN-A-LIEN, M. (1986): Generation and migration of hydrocarbons in the Maracaibo Basin, Venezuela: An integrated basin study. Organic Geochemistry, 10(1-3), 261-279.

ZUMBERGE JOHN, E. (1984): Source rocks of the La Luna Formation (Upper Cretaceous) in the Middle Magdalena Valley, Colombia. AAPG Studies in Geology #18, Petroleum Geochemistry and Source Rock Potential of Carbonate Rocks, 127-33.

Some Contributions for Research of Condensation Corrosion in Caves (Dinaric Karst, Croatia)

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The research on the prevalence of condensation corrosion in speleogenesis have been conducted in the Karst of Croatian coast for the first time. It is the instalment of the international project. Condensation corrosion in caves occurs on cold rock surface in contact with the warm and humid air coming from the terrain surface. A thin layer of water appears on the rock surface and reacts chemically with it. This process is very noticeable on the cave entrances in the arid areas when the hot air from the surface rapidly enters the cold caves.

Condensation corrosion forms round shapes on the rocks, domes, sometimes similar to "vortex pots" on the ceilings and corroded speleothems.

Extraordinary examples of condensation corrosion have been found in some coves in the coastal area of Croatian Karst where the temperature gradients are more expressed. The air humidity in the parts of the caves closer to the terrain surface can be changed due to the effects of strong winds (Bura, Jugo etc.). Examples of such condensation corrosion were noticed in several vertical caves near Maslenica and on Murter Island (Fig. 1). Due to the vicinity of the sea the effects of salinization are sometimes also found on the cave entrances.

In the research conducted in Cyprus (CAILHOL et al., 2019) condensation corrosion correlated with the larger colonies of bats in the caves. Namely, the metabolism of bats and the chemical decomposition of guano change the temperature, humidity and acidity of the cave (AUDRA et al., 2018). Such research in the sense of condensation corrosion have not been conducted before in Croatia.

Caves included in the research along the Croatian coast are speleogenetically linked to Cretaceous or Eocene dolomitic limestones and limestones. The majority of caves are tied to neo-tectonic rising of the primary blocks. The altitude of their entrances today is approximately 100 meters above sea level. In some caves the concentration of radon gas was measured. The results of which were slightly higher than the average concentrations measured in the caves of that area. But so far the data cloud is too small to draw conclusions.

Figure 1. Condensation corrosion speleothems in cave on Murter island (photo: Garašić).

Keywords: *karst, caves, condensation corrosion, speleology, Croatia*

References

AUDRA, P., BARRIQUAND, L., BIGOT, J.-Y, CAIHOL, D., CAILLAUD, H., VANARA, N., NOBECOURT, J.-C., MADONIA, G., VATTANO, M. & RENDA, M. (2018) : L'impact méconnu des chauves-souris et du guano dans l'évolution morphologique tardive des cavernes (The little known impact of bats and bat guano in the late stages of cave morphogenesis). Karstologia, 68, 1-20.

CAILHOL, D., AUDRA, P., NEHME, C., NADER, F., GARAŠIĆ, M., HERESANU, V., GUCEL, S., CHARALAMBIDOU, I., SATTERFIELD, L., CHENG, H. & EDWARDS, L.R. (2019): The Contribution of Condensation Corrosion in the Morphological evolution of caves in semi-arid regions- preliminary investigations in The Kyrenia Range, Cyprus. Acta Carsologica, 48/1, 9-31.

Comparison of Jurassic Sedimentary Mélanges in the Circum Pannonian Orogens (Western Tethys)

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Component analyses of ancient Neo-Tethys mélanges along the Eastern Mediterranean mountain ranges allow both, a facies reconstruction of the Middle Triassic to Middle Jurassic outer passive margin of the Neo-Tethys and conclusions on the processes and timing of the Jurassic orogenesis. This Middle-Late Jurassic mountain building process in the Western Tethyan realm was triggered by west- to northwestward-directed ophiolite obduction onto the former passive continental margin of the Neo-Tethys.

Ophiolite obduction onto the former passive continental margin started in the Bajocian and trench-like deep-water basins formed in sequence within the northwest-/westward propagating nappe fronts in the footwall of the obducting ophiolites. Deposition in these basins was characterized by coarsening-upward cycles, i.e. forming sedimentary mélanges as synorogenic sediments, in cases tectonically overprinted. In the Middle Jurassic, the oceanic realm and the most distal parts of the former passive margin were incorporated into the nappe stacking. Bajocian-Callovian ophiolitic and Meliata mélanges were formed as most oceanward preserved relics of trench-like basins in front of the propagating ophiolitic nappe stack, often with incorporated components from the continental slope. In the course of ongoing ophiolite obduction, thrusting progressed to the outer shelf region (Hallstatt Limestone facies zone). In Bathonian/Callovian to Early Oxfordian times the Hallstatt nappes with the Hallstatt mélanges were established, expressed by the formation of the up to 900 m thick basin fills comprising its material mainly from the outer shelf region. In Callovian to Middle Oxfordian times the nappe stack reached the former carbonate platform influenced outer shelf region. Newly formed basins received material from this shelf region, occasionally mixed with material from the approaching ophiolite nappes. Ongoing shortening led to the formation of the proximal Hallstatt nappes with concomitant mobilisation of Hallstatt Mélanges. Persistent tectonic convergence caused the partial detachment and northwest- to west-directed transport of the older basin groups and nappes originally formed in a more oceanward position onto the foreland.

Comparison of mélanges identical in age and component spectrum in different mountain belts (Eastern Alps/Western Carpathians/Dinarides/Albanides/Pelso) figured out one Neo-Tethys Ocean in the Western Tethyan realm, instead of multi-ocean and multi-continent scenarios. The evolution of several independent Triassic-Jurassic oceans is unlikely considering the fact that re-sedimentation into newly formed trench-like basins in front of a west- to northwestward propagating nappe stack including ophiolite obduction is nearly contemporaneous along the Neotethyan Belt. The Middle to Late Jurassic basin evolutions with their sedimentary cycles and component spectra are comparable everywhere.

Mineral Resources in Central Croatia: Geological Potentiality and Strategic Importance

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The aim of this paper is to give a summary of Croatia's mineral resource potential in its central part. Research covered central part of Croatia, which is generally build from Quaternary sediments of Pannonian basin (95 %) and a smaller part of magmatic and metamorphic rocks (5%). Within the lithological members of the investigated area, as valuable mineral raw materials are crushed stone, sand and gravel, brick clay and quartz sand. The initial search for the optimal location for a mineral extraction site is complex, involving consideration of geology, environment, market, transport and other factors.

Particularly for these purposes, a geological map of the wider area was first developed (DEDIĆ et al., 2018, 2019; KRUK et al., 2015). Exploitation fields and exploration areas are shown in the next step, based on the geological material of the subject area and the lithological characteristics of rocks that may contain useful mineral raw materials, explorations on existing exploitation fields or exploration sites and abandoned dumps with their occurrence frequencies. A map of the geological potential of mineral raw materials, which shows the natural propagation of certain types of mineral raw materials was created. Taking into account spatial planning, legal restrictions or prohibitions in the area results in the physical planning map with conflict zones and bans.

The potential market for mineral resources was evaluated using population density, proximity to urban areas, housing targets and priorities for highway improvements. Distances to main roads were also examined. All these aspects were weighted using expert opinions. The degree of constraint imposed by various environmental designations was assessed and mapped. The final product is the map of the geological potential in conflict zones and bans.

In this research, a geographical information system (GIS) was used as a spatial decision support tool to combine all of these aspects and to map the potential for mineral resources extraction. It moves beyond simple mapping of the extent of mineral resources to examine the potential of an area to be suitable for mineral extraction.

Such maps represent a useful decision-making tool for Mineral Planning Authorities and quarry operators. Although, the paper focussed on mineral resources extraction in the central Croatia, the methodology developed could be used for any other region, and geological potentially for other minerals.

Keywords: *mineral resource, geological potential, central Croatia, spatial planning, GIS*

References

DEDIĆ, Ž., KRUK, B., AVANIĆ, R., KUREČIĆ, T., KRUK, LJ., GIZDAVEC, N., KOVAČEVIĆ GALOVIĆ, E., KOLBAH, S. & ŠKRLEC, M. (2019): Rudarsko-geološka studija Bjelovarsko-bilogorske županije. [Mining – Geological study of Bjelovar - Bilogora county]. Fond stručne dokumentacije 24/19, Hrvatski geološki institut, Zagreb.

DEDIĆ, Ž., KRUK, B., AVANIĆ, R., PEH, Z., KRUK, LJ., KOVAČEVIĆ GALOVIĆ, E., KOLBAH, S., ŠKRLEC, M. & CRNOGAJ, S. (2016): Rudarsko-geološka studija Sisačko-moslavačke županije. [Mining – Geological study of Sisak - Moslavina county]. Fond stručne dokumentacije 06/16, Hrvatski geološki institut, Zagreb.

KRUK, B., DEDIĆ, Ž., HEĆIMOVIĆ, I., KRUK, LJ., KOLBAH, S., ŠKRLEC, M., CRNOGAJ, S. & KOVAČEVIĆ GALOVIĆ, E. (2015): Rudarsko-geološka studija Koprivničko-križevačke županije. [Mining – Geological study of Koprivnica - Križevci county]. Fond stručne dokumentacije 61/14, Hrvatski geološki institut, Zagreb.

Modified Wet Sieving Preparation Technique in Palaeontology

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Wet-sieving techniques are common analytical procedures in various fields of science and technology. In palaeontology they are commonly used for extraction of microfossils from bulk rocks (e.g. HULME, 1961, HARRIS & SWEET, 1989; NIELSEN & JAKOBSEN, 2004). Rock samples are usually crashed into small pieces, soaked in water, sometimes with added small amount of hydrogen peroxide. After 24 hours, partly dissolved samples are washed out through a system of sieves manually, or in an appropriate instrument. During this process, a part of the sample often remains undissolved, sometimes entrapping important part of the fossil assemblage. Therefore some modifications of the method were proposed (e.g. by NIELSEN & JAKOBSEN, 2004). They freezed the soaked sample for at least 24 hours, then thawed it in hot water and repeated this process several times before sieving the sample. According to their observations, they found such preparation more effective than classic wet-sieving, obtaining well-cleaned microfossil tests.

During this research, bulk Miocene sedimentary rocks with different amount of calcareous component were chosen for comparison of the classic and some new preparation techniques. These were: 1. Early-Middle Miocene lacustrine argillaceous marls; 2. Middle Miocene marine argillaceous limestones. Rock samples were collected in the vicinity of Planina in eastern Medvednica Mt. (Sample 1) and Dubravica in south-western part of the Medvednica Mt. (Samples 2 and 3). Each of the samples was separated into three equal piles. The first pile was treated by a classic wet sieving technique (soaking in water and wet sieving after 24 hours). The second pile was soaked in water, frozen for 24 hours and defrosted in hot water. After the cooling the whole procedure was repeated for at least two more times and then wet-sieved. The third pile was soaked in water, frozen for 24 hours and defrosted in a microwave oven. After the cooling the whole procedure was repeated for at least two more times and then wet-sieved.

The results were the following:

Fossils from Sample 1 (lacustrine argillaceous marl, 18% carbonate component), ostracods, mollusks and fish remains, were equally preserved or even more poorly preserved, when applying freezing-heating process.

Fossils from Sample 2 (marine argillaceous limestone, 79% carbonate component), foraminifera, ostracods, echinoids, were slightly better cleaned when freezing-heating process was applied. The best, but not spectacular results were obtained by heating in a microwave oven.

Fossils from Sample 3 (marine argillaceous limestone, 77% carbonate component), foraminifera, ostracods, echinoids, were slightly better cleaned when freezing-heating process was applied. We did not observe difference between water-heated and microwave-heated piles. Nevertheless, microwave-treated pile was the best disintegrated, and water-sieving process was much shortened and more efficient.

According to this research, we can recommend the application of freezing-microwave heating technique before the wet-sieving for argillaceous limestones. Method was not efficient for highly argillaceous samples. These results can be well compared with freezing-water heating experiment performed on carbonate samples by NIELSEN & JAKOBSEN (2004), who obtained good results in extraction and preservation of fossil tests.

Keywords: *sedimentary rocks, freezing, water heating, microwave heating, wet-sieving*

References

HARRIS, A.G. & SWEET, W.C. (1989): Mechanical and chemical techniques for separating microfossils from rock, sediment, and residue matrix. In: FELDMANN, R.M., CHAPMAN R.E & HANNIBAL, J.T. (eds.): Paleotechniques. Paleontological Society Special Publications, 4, 70-86.

HULME, S.G. (1961): A Mechanized Method of Breaking down and Washing Foraminiferal Rock Samples. Micropaleontology, 7(1), 107-113.

NIELSEN, J.K. & JAKOBSEN, S.L. (2004): Extraction of Calcareous Macrofossils from the Upper Cretaceous White Chalk and Other Sedimentary Carbonates in Denmark and Sweden: The Acid-Hot Water Method and the Waterblasting Technique. Palaeontologia Electronica, 7(4), 1-11.

Mollusc-Rich Facies along Late Cretaceous Margin of the Adriatic Carbonate Platform: Intra- or Inter-Platform Trough? (Neum Hinterland, Southern Herzegovina and Central Dalmatia)

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The region of southernmost Herzegovina is composed mostly of the shallow-water carbonates of the Adriatic carbonate platform (VLAHOVIĆ et al., 2005), deformed during the Alpine orogenesis and included into the High Karst tectonic unit of the External Dinarides (CHOROWICZ, 1975; KORBAR, 2009). The uppermost Cretaceous succession in the wider area is characterized by typical platform-top peritidal carbonates, palaeokarstified during the Late Cretaceous to Eocene exposure, and is unconformably overlain by Paleogene Foraminiferal limestones. However, on the Basic geological map of the area (RAIĆ et al., 1982), Paleocene limestone breccia and overlying marls appear along an interesting narrow tectonic zone Brestica-Kiševo-Moševići (Fig. 1). Recent detail fieldwork in Neum hinterland resulted with discoveries of interesting fossils and ichnofossils in the Upper Cretaceous carbonates (http://hercegovina-geoarheo.blogspot.com/), including association of coarse-grained carbonates and molluscs-rich facies characterized by unusual abundance of rudists and gastropods.

The association appear along the aforementioned tectonic zone striking NW-SE (Dinaridic strike).

Preliminary stratigraphical data suggests that lower part of the Upper Cretaceous succession is characterized by thick-bedded to massive Cenomanian Chondrodonta limestones that pass upward into the Turonian to Coniacian laterally various marginal open-platform facies. Massive carbonate clastics (bioclastic-intraclastic breccia) interfinger laterally with the massive rudist-gastropod floatstones that include also hippuritids in growth position. The recrystallized coarse-grained bioclastic limestones laterally interfinger with irregular meters to decameters bodies of lithoclastic breccia. On the weathered surfaces of the limestone, compact-shell bioclasts and whole rudist shells can be recognized. There are mostly radiolitids and hippuritids in autochthonous and para-autochthonous position. Loose communities of Vaccinites and Hippurites are found in life position, while gastropod shells appear grouped in floatstones that interfinger with the coarser-grained limestone lithotypes. Coniacian age of the association is proposed according to abundant specimens of relativelly small Vaccinites cornuvaccinum ((BRONN) STEUBER et al., 2005). The abundance of molluscs, especially hippuritid rudists, suggests fully open-marine circulation and platform margin depositional environment (STÖSSEL & BERNOULLI, 2000), while the lithoclastic breccia bodies suggest syn-sedimentary redeposition, probably along the

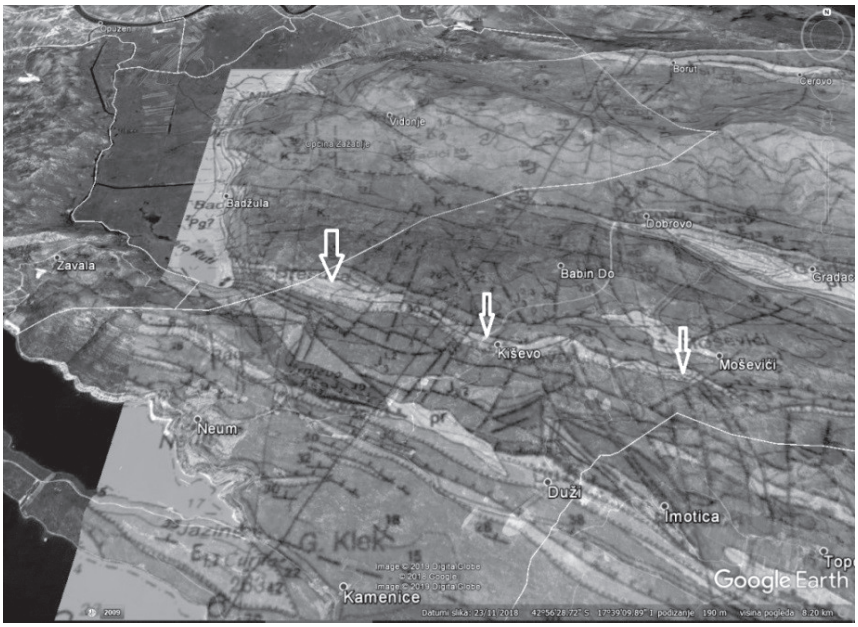

Figure 1. Panoramic view on the area covered with the Basic Geological Map 1:100.000 sheet Ston (RAIĆ et al., 1982; Google Earth) with arrows that indicate the investigated zone Brestica-Kiševo-Moševići.

slope. The mollusc-rich Turonian-Coniacian limestones are palaeokarstified at the top and unconformably(?) overlain by Paleogene(?) marls. Thus, further research will be focused on the age of the overlying marls and to the more detail mapping of the facies, and to the tectonic contacts with the High Karst unit (*s. str.*).

The Brestica-Kiševo-Moševići zone is probably SE continuation of the complex tectonostratigraphic zone called the "Kotišina-Tilovica" trough (JELASKA et al., 2003; ĆOSOVIĆ et al., 2006), or the NorthEastern Adriatic Trough (NEAT cf. KORBAR, 2009), the paleogeographical entity separating Dinaridic platform (*s. str*.) north of the trough, and the Adriatic platform (*s. str*.) south of the trough in the region of present-day central Dalmatia. The trough is characterized by deeper-water carbonates, mostly carbonate (slope) breccia deposited during Maastrichtian to Paleocene emergence of the platform top, and probably represents the NW continuation of the Triassic to Paleogene Budva basin (CHOROWICZ, 1975; KORBAR, 2009). However, preliminary data suggest a complicated tectonic structure in this part of the External Dinarides, and the outcropping marginal part of the trough is probably only a small portion of once wider intra/inter(?) platform basin tectonically compressed during the main phase of the Alpine orogenesis in the region.

Keywords: *Turonian-Coniacian, carbonate platform margin, rudists, gastropods, External Dinarides*

References

CHOROWICZ, J. (1975): Le devenir de la zone de Budva vers le Nord-Ouest de la Yougoslavie. Bull. Soc. Géol. France, 7/17, 699-709.

ĆOSOVIĆ, V., PREMEC FUĆEK, V., GUŠIĆ, I., JELASKA, V. & MORO, A. (2006): The age of the Tilovica breccias in Central Dalmatia, Croatia. Micropaleontology, 52, 281-286.

JELASKA, V., BENČEK, Đ., CVETKO TEŠOVIĆ, B., ĆOSOVIĆ, V., GUŠIĆ, I., IŠTUK, Ž. & MATIČEC, D. (2003): Platform Dynamics During the Late Cretaceous and Early Palaeogene – External Dinarides, Dalmatia. In: VLAHOVIĆ, I. & TIŠLJAR, J. (eds.): Evolution of Depositional Environments from the Palaeozoic to the Quaternary in the Karst Dinarides and Pannonian Basin, 22nd IAS Meeting of Sedimentology, Opatija – September 17-19, 2003, Field Trip Guidebook, 101-107, Zagreb.

KORBAR, T. (2009): Orogenic evolution of the External Dinarides in the NE Adriatic region: a model constrained by tectonostratigraphy of Upper Cretaceous to Paleogene carbonates. Earth Science Reviews, 96/4, 296-312.

RAIĆ, V., PAPEŠ, J., AHAC, A., KOROLIJA, B., BOROVIĆ, I., GRIMANI, I. & MARINČIĆ, S. (1982.): Osnovna geološka karta SFRJ 1: 100 000: List Ston K 33-48. – Geoinženjering – OOUR Institut za geologiju, Sarajevo, (1972.-1980.). Institut za geološka istraživanja, Zagreb, (1967.-1968.), Savezni geološki institut, Beograd, 1980.

STEUBER, T., KORBAR, T., JELASKA, V. & GUŠIĆ, I. (2005): Strontium-isotope stratigraphy of Upper Cretaceous platform carbonates of the island of Brač (Adriatic Sea, Croatia): Implications for global correlation of platform evolution and biostratigraphy. Cretaceous Research, 26/5, 741-756.

STÖSSEL, I. & BERNOULLI, D. (2000): Rudist lithosome development on the Maiella Carbonate Platform margin. In: INSALACO, E., SKELTON, P.W. & PALMER, T.J. (eds.): Carbonate Platform Systems: components and interactions, Geological Society, London, Spec. Public., 178, 177-190.

VLAHOVIĆ, I., TIŠLJAR, J., VELIĆ, I. & MATIČEC, D. (2005): Evolution of the Adriatic Carbonate Platform: Palaeogeography, main events and depositional dynamics.-Palaeogeography, Palaeoclimatology, Palaeoecology, 220/3-4, 333-360.

Slumps as Indicators of Basin Geometry and Development – Examples from the Promina Beds in Northern Dalmatia

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The Promina Beds in northern Dalmatia are a more than 2000 m thick calciclastic succession of Middle Eocene–Early Oligocene age, constituting the infill of the *piggyback* part of the Dinaric Foreland Basin (Fig. 1A, 1B; MRINJEK et al., 2011; ĆOSOVIĆ et al., 2018). Progressive thrusting due to the collision between Africa and Europe compartmentalized the basin and led to the formation of an array of narrow marine sub-basins, separated from one another by ridges developed on blind-thrust growth folds. These sub-basins had steep flanks, whereby dynamic synsedimentary tectonic activity resulted in drastic facies changes over short distances, including frequent slumping.

Slumps in the Promina Beds occur in marine deposits of different age and in different sub-basins (Fig. 1B). They commonly display contorted strata (Fig. 1C–1E) and evidence of sediment torsion, resulting from gravitational

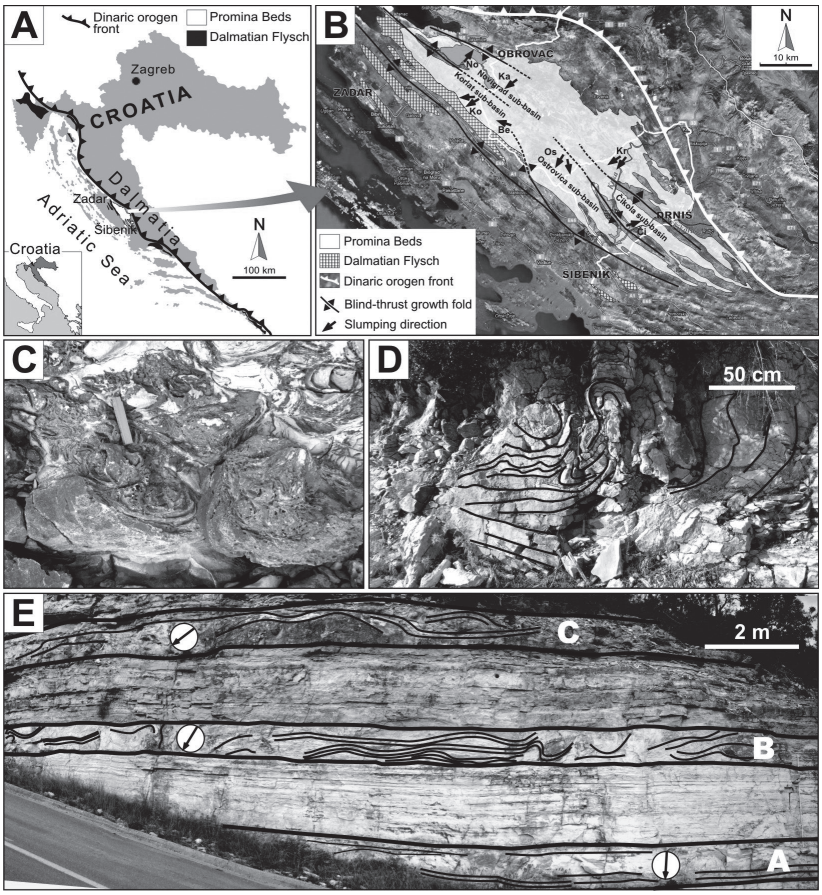

Figure 1. (A) Regional extent of the Dinaric orogen front and location of the Promina Beds. (B) Generalized map showing the extent of the Promina Beds and Dalmatian Flysch in northern Dalmatia. Arrows indicate slumping directions at documented localities: No – Novigrad, Ka – Karin, Ko – Korlat, Be – Benkovac, Os – Ostrovica, Kr – Krka canyon, Či – Čikola canyon. (Modified after ĆOSOVIĆ et al., 2018). (C) One of the slumps at locality Novigrad. Scale is 12 cm long. (D) One of the slumps along the road towards the Krka canyon. (E) Outcrop section with three slump intervals (A, B and C) along the road towards the Krka canyon. Slumping direction is marked in circles: A towards the south, B and C towards the southwest.

en masse movement of sediment along steep and unstable slopes. Their transport direction can be inferred from their geometry and in most cases it is perpendicular to the south-east-trending structural lineaments (Fig. 1B). Most of the documented slumps show transport direction towards the south-west (Fig. 1B, 1E). These observations indicate that the sub-basins were likely asymmetrical, i.e. steeper along their NE margin, which increased slope instability and its susceptibility to repeated slumping. Alternatively, tectonic perturbations associated with progressive nappe thrusting might have been more severe along the sub-basins' NE margins. Slumps are locally associated with micro-faults formed in fairly coherent sediment, resembling the segmented zone of a typical seismite (SEILACHER, 1969), which corroborates the latter assumption and suggests that slumps were most likely triggered by earthquakes and enhanced by steep basin morphology. In places, however, slumped deposits were emplaced from other directions and could have been triggered by major regional earthquakes or locally oversteepened north-eastern anticline limbs. By assessing slump directions and age of the deposits in which they are encased, it is possible to reconstruct basin development dynamics, e.g., discern between in-sequence and out-of-sequence thrusts or identify possible blind-thrust anticlines that nowadays may be concealed by topography or sediment cover.

Keywords: Dinaric Foreland Basin, Promina Beds, slumping direction, sub-basin geometry

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, 746-765.

MRINJEK, E., PENCINGER, V., NEMEC, W., VLAHOVIĆ, I. & MATIČEC, D. (2011): The effects of blind-thrust folding on foreland sedimentation: examples from the Eocene–Oligocene Dinaric foreland basin of Croatia. Abstracts, 28th IAS Meeting, Zaragoza, Spain, 443.

SEILACHER, A. (1969): Fault-graded beds interpreted as seismites. Sedimentology, 13, 155-159.

Tetrahedral Charge of Bentonites from Croatia and Neighbouring Countries

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Bentonites as important industrial minerals have versatile applications. The applications depend on their mineralogical, structural and chemical characteristics. One of such properties is the location of charge that can originate from substitutions either in the tetrahedral or octahedral layer. Therefore, this study was focused on tetrahedral charge determination of 12 bentonite samples, from 10 localities in Croatia and neighbouring countries, that were already the subject of earlier investigations e.g. GVERIĆ et al. (2018). Locations of samples are the following: Bednja, Bunarić, Divoselo, Draga, Lončarski Vis, Paripovac, Poljanska Luka and Sjeničak (Croatia); Šipovo (Bosnia and Herzegovina); Vranjska Banja (Serbia). In earlier research chemical composition (ICP/AES and ICP/MS) and mineral composition (XRD and IR) were determined. Thermal analyses and CEC determination had been made as well. Earlier investigations showed discrepancies between layer charge determined by chemical formulae calculations using chemical analysis data and those determined experimentally by observing the swelling behaviour of potassium saturated samples solvated with ethylene glycol. In order to better define their layer charge, especially the tetrahedral one, additional analyses were done. Percent of tetrahedral charge was determined by slightly modified procedure of KAUFHOLD et al. (2017), namely by measuring the CEC (copper ethylenediamine complex method) before and after treatment with 1.5 M LiCl solution. During the heating of Li-saturated samples, Li migrates within the structure to compensate for octahedral charge deficiency, therefore the CEC measured after Li saturation is a result of tetrahedral charge only. Full width at half maximum (FWHM) of d_{001} reflection of Cu_{dien}-exchanged bentonites was also determined since it is known that it is correlated with tetrahedral charge (KAUFHOLD et al., 2011). Additionally iron (II) content (FeO), which can influence layer charge values obtained by chemical formulae calculations, was determined by Mössbauer spectroscopy and Wilson method (WILSON, 1955). Tetrahedral charge values, expressed in % of total charge, obtained by CEC measurements were compared to those obtained by chemical formulae calculations (Fig. 1). CEC measurements showed that all of the samples, according to the classification scheme proposed by EMMERICH et al. (2009), can be classified as beidellitic montmorillonites. Chemical formulae calculation method confirmed the dominance of beidellitic montmorillonites among investigated samples. There are two exceptions; one of the samples should be classified as montmorillonitic beidellite while another should be classified as beidellite. Performed analyses (both methods) showed that Fe (II) is absent or present in very low quantities (in <2μm fraction up to 0.91 wt% FeO which correspond to 15.3 % of total Fe).

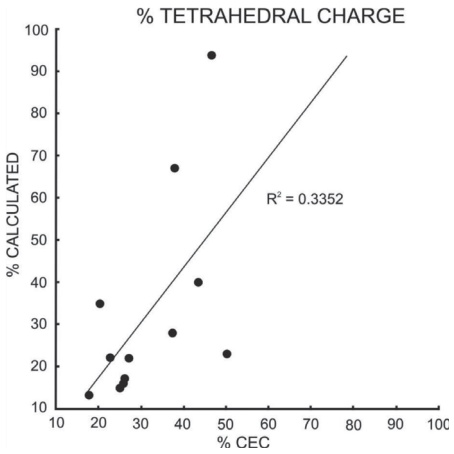

Figure 1. Comparison of tetrahedral share of total charge (in %) obtained by CEC measurement, according to procedure described in KAUFHOLD et al. (2017), and chemical formulae calculation.

Keywords: bentonite, tetrahedral charge, Croatia

References

EMMERICH, K., WOLTERS, F., KAHR, G. & LAGALY, G. (2009): Clay profiling: The classification of montmorillonites. Clays Clay Miner., 57, 1, 104-114.

GVERIĆ, Z., PLEŠA, A. & TIBLJAŠ, D. (2018): Comprehensive characterisation of bentonites from Croatia and neighbouring countries. In: DZENE, L. & VIRCAVA, I. (eds.): II International Symposium "Clays and Ceramics", Riga. Book of Abstracts, 20-21.

KAUFHOLD, S., DOHRMANN, R., UFER, K., KLEEBERG, R. & STANJEK, H. (2011): Termination of swelling capacity of smectites by Cu_{trien} exchange. Clay Miner., 46, 411-420.

KAUFHOLD, S., STUCKI, J.W., FINCK, N., STEININGER, R., ZIMINA, A., DOHRMANN, R., UFER, K., PENTRÁK, M. & PENTRÁKOVÁ, L. (2017): Tetrahedral charge and Fe content in dioctahedral smectites. Clay Miner., 52, 51-65.

WILSON, A.D. (1955): A new method for the determination of ferrous iron in rocks and minerals. Bull. Geol. Surv. G. B., 9, 56-58.

Introducing Kindergarten Children to Geological Science

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The aim of this study is to encourage preschool children's introduction to geology as an integral part of the environment, or more precisely, the nature that surrounds us. The research was conducted in the kindergarten "Iskrica" in Zagreb. A geological display was used in the research, which was composed of samples of fossils, minerals and rocks.

The goal of the research is to explore the children's introduction to geological science as a part of natural sciences. The research has been carried out by examining their prior knowledge through introductory questions, trying to introduce them to geological science through activities and then checking their potentially newly adopted knowledge through further activities.

The research was conducted through two activities over two days and in which participated fourteen children ages three to seven. The first activity was carried out in such a way that the children approached the geological display lead by their own interest and asked questions about the collection, whose parts they could also take, touch etc. After that, the children worked with clay and drew.

The second activity was conceived to be conducted through teaching, but the children did not react well to this method so it was abandoned. Following that, the display was shown to the children accompanied by a story, in which they participated by asking questions, suggesting which samples should be included in the story, etc. In addition to this, they could also browse and touch the geology display as well as ask questions about it. At the end of the activity, the children worked with clay, drew and played an interactive game on the subject of the activity and the display.

It can be concluded that it is possible to successfully introduce children to geology as a natural science. It is also evident that it is also possible to introduce children to such a science using different work methods. Except for the geological themes used in this study and the already carried out activities, these themes can be further expanded.

Keywords: children, geology, geological display

Microbial Sediments from the Upper Triassic Main Dolomite Formation of Žumberak Mts. (Northwestern Croatia)

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Dolomite has been considered as one of the biggest geological problems. It is very rare in modern sediments and has the inability to synthesize under low-temperature conditions in the laboratory, so the origin of dolomite has remained an enigma in sedimentology, often called the 'Dolomite Problem' (McKENZIE & VASCONCELOS, 2009). Many dolomitisation theories has been established but have difficulties to explain vast (both in thickness and regional extent) Main Dolomite Formation *(Hauptdolomite, Dolomia Principale)*. Main Dolomite has thickness up to 2000 m, and is spread all through wider Alpine area, consist entirely of dolomite, with limestone intercalations only in the uppermost part near the transition to the Dachstein Limestone. Only discovery of VASCONCELOS & McKENZIE (1997, and later papers) has provided new understanding of the mechanisms that is involved in the primary dolomite precipitation under Earth surface conditions, in contrary to other theories that included secondary replacement of meta-stable calcium carbonates. Authors develop the "Microbial dolomite model" based on a study of a modern dolomite-forming hypersaline coastal lagoon, Lagoa Vermelha, Brazil, where sulphate-reducing bacteria induce dolomite precipitation. That conclusion was confirmed by culture experiments.

Bacteria are not only crucial for production of dolomite in Lagoa Vermelha case, but also are part of microbial mat communities that form stromatolites (SPADAFORA et al., 2009). It is very interesting that stromatolite taken from Lagoa Vermelha continues to grow in aquarium, where no trapping and binding of sediment is possible.

MASTANDREA et al. (2006) found in stromatolitic facies of the Main Dolomite in Southern Italy small round structures that they interpret as fossilized bacteria, supposedly similar to the living ones from Lagoa Vermelha.

The other 'problem' with the Main Dolomite is the origin of sediments, although this topic is not much discussed in literature. The origin of sediments that formed limestone is well known, thanks to investigations of modern carbonate platform environments. The Main Dolomite has almost no fossil remnants, and its structure, when preserved, consists mainly of micritic particles. ZANKL & MERZ (1994) investigated cyanobacteria from Everglades swamp (USA) and found out that quantity of carbonate sediments that cyanobacteria precipitate corresponds to the sedimentation rates calculated for the Main Dolomite.

Presented solution of these two 'geological problems' enables us to consider the Main Dolomite as a paragon of a microbial rock (or microbialite).

The Main Dolomite *(Glavni dolomit)* is present also in Žumberak Mts. in northwest Croatia. There it lies between dolomites of Carnian Slapnica Formation and dolomites (with rare limestone intercalations) of Rhaetian Posinak Formation (GRGASOVIĆ, 1997; GRGASOVIĆ, 2007; GRGASOVIĆ et al., 2007). In the uppermost part of the Main Dolomite, an interval of intraformational tempestite dolomite breccia of Kalje Member is separated. The geological age of the Main Dolomite in this area is Norian-Rhaetian, based on foraminifera and calcareous algae biozonation (GRGASOVIĆ, 1997).

The Main Dolomite is characterised by the frequent alternation of three lithofacies: dolomicrites, fenestral dolomicrites and dolostromatolites, all presumably of microbial origin.

The dolomicrite lithofacies predominates over the others. It contains dense mass of micritic particles or minute peloids and aggregated grains, with rare intraclasts. Most often has been diagenetically changed to dolomicrosparite. Sedimentary environment is interpreted as subtidal. The origin of mud particles is probably from cyanobacteria, as suggested by ZANKL & MERZ (1994).

The fenestral dolomicrite lithofacies has typical micobialite characteristics, and it is stromatolite actually, but to distinguish it from the next member it was named 'fenestral dolomicrite', since it is characterized by lamellar and irregular fenestrae, with geopetal filling due to vadose intertidal environment. It consists of a matrix of minute peloids and trombolites, originated possibly by trapping and binding of subtidal carbonate mud to intertidal microbial mats. It would, according to RIDING (1991) correspond to 'agglutinated stromatolites'.

Dolostromatolite lithofacies are the most prominent characteristic of the Main Dolomite Formation. They are very finely wavy laminated, so they have been colloquially called 'microwave' stromatolite. They have a much darker colour than other structural types. These stromatolites are built of very small sediment particles that were probably precipitated by microbes in microbial mats (as suggested by SPADAFORA et al. (2009)), and of thin micritic tubes that represent cyanobacterial skeletons as well. It would, according to RIDING (1991), correspond to 'skeletal stromatolite'. Between the laminae built of micrite particles and cyanobacterial skeletons there are thin lamellar fenestrae which suggest an intertidal to supratidal sedimentary environment.

Both 'fenestral dolomicrite' and 'dolostromatolite' lithofacies has completely preservative structure, meaning that all components of microfacies, from the thinnest mud particle to coarse-grained cement, is fully preserved, and in thin section cannot be distinguished from the limestone microfacies, so we use Alizarin colouring to prove 100% dolomite mineralogy. Also, rare fossils are preserved, that enabled their detailed investigation (GRGASOVIĆ, 1997; SOKAČ & GRGASOVIĆ, 1998). Such preservation suggests a model of very fast and early dolomitisation, as "Microbial dolomite model" of VASCONCELOS & McKENZIE (1997). Dolomicrite lithofacies has been fully dolomitised somewhat later during diagenesis, as suggested by larger crystals, although the initial dolomitisation can be also explained by above mentioned model.

Keywords: stromatolites, microbial sediments, Upper Triassic, Main Dolomite, Žumberak Mts.

References

GRGASOVIĆ, T. (1997): Upper Triassic biostratigraphy and algae from Žumberak (Croatia). Geol. Croatica, 50/2, 201-214.

GRGASOVIĆ, T. (2007): Overview of the geology of Žumberak and Samoborsko gorje. In: GRGASOVIĆ, T. & VLAHOVIĆ, I. (ed.): 9th International Symposium on Fossil Algae, Field-Trip Guidebook and Abstracts. Hrvatski geološki institut, 137-142, 2 fig., Zagreb.

GRGASOVIĆ, T. & KOCH, G. & GLOVACKI JERNEJ, Ž. (2007): Stop 8 – Slapnica valley – Norian strata. In: GRGASOVIĆ, T. & VLAHOVIĆ, I. (ed.): 9th International Symposium on Fossil Algae, Field-Trip Guidebook and Abstracts. Hrvatski geološki institut, 189-192, 3 fig., Zagreb.

MASTANDREA, A., PERRI, E., RUSSO, F., SPADAFORA, A. & TUCKER, M. (2006): Microbial primary dolomite from a Norian carbonate platform: northern Calabria, southern Italy. Sedimentology, 53, 465-480.

McKENZIE, J.A. & VASCONCELOS, C. (2009): Dolomite Mountains and the origin of the dolomite rock of which they mainly consist: historical developments and new perspectives. Sedimentology, 56, 205-219.

RIDING, R. (1991): Classification of microbial carbonates. In: RIDING, R. (ed.): Calcareous Algae and Stromatolites. Springer-Verlag, Berlin, 21-51.

References

SOKAČ, B. & GRGASOVIĆ, T. (1998): *Asterocalculus heraki* n.gen., n.sp., a new calcareous alga (Gymnocodiaceae) from the Upper Triassic Hauptdolomite of Žumberak, north Croatia. Facies, 38, 197-206.

SPADAFORA, A., PERRI, E., McKENZIE, J.A. & VASCONCELOS, C. (2010): Microbial biomineralization processes forming modern Ca:Mg carbonate stromatolites. Sedimentology, 57, 27-40.

ZANKL, H. & MERZ, M. (1994): The possible contribution of fresh water cyanobacteria to Northern Alpine Hauptdolomit sedimentation. Beiträge zur Paläontologie von Österreich, 19, 261-264.

Geochemical and Mineralogical Characteristics of Alluvial Quaternary Sediments on the Slopes of Medvednica Mt. (Croatia)

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During research for the Basic Geological Map of Republic of Croatia 1:50 000 and Croatian Science Foundation Project No. 4425 - SAPIQ, alluvial Quaternary sediments on the slopes of Medvednica Mt. which belong to the informal lithostratigraphic unit Bistra Formation (AVANIĆ et al., 2006; GRIZELJ et al., 2017), were studied using several different approaches. Geochemical analysis included determination of major and trace element compositions using inductively coupled plasma emission spectroscopy (ICP-ES) and inductively coupled plasma mass spectrometer (ICP-MS). Mineralogical-petrological analysis included: microscope analysis of unconsolidated sedimentary rocks, heavy minerals analysis and X-ray powder diffraction (XRPD). Palynological analyses were used for paleoenvironment reconstruction. The interpretation of the depositional environment and the provenance of the sediments are based on the obtained data.

The informal Bistra Formation lies unconformably on the Pannonian informal Formations Medvedski Breg or Andraševec. It consists of gravely, sandy, silty and clayey poorly sorted sediments which were deposited in an alluvial environment in the area of sheet flows, crevasse splays, longitudinal bars and flood plains. It is overlaid by loess-like sediments and fluvial Holocene sediments. The chronostratigraphic position of the informal Bistra Formation is still under debate due to a lack of absolute dating results, but according to palynological data and superposition it is assumed to be of Pleistocene age.

The main mineral components of clayey sediments are quartz, feldspar, swelling clays (vermiculite and/or smectite), illite/muscovite and in a lesser quantity kaolinite and chlorite. The composition of gravels and the presents of epidote group minerals in the heavy mineral fraction of silty sand sediments indicate a derivation of detritus from different types of schist rocks occurring on Medvednica Mt. On the other hand, quartz grains and chert fragments in the light mineral fraction of the silty sand sediments, together with elemental ratios critical of provenance (LREE/HREE, Eu/Eu*, La/Sc, Th/Sc, Th/Co, Th/Cr and La/Co) and the source rock discriminant diagram of ROSER & KORSH (1988) imply that the source were different types of rocks, but predominantly acidic (silicic) rocks.

Keywords: Bistra Formation, Quarternary, Medvednica Mt., alluvial sediments, provenance

References

AVANIĆ, R., BAKRAČ, K., GRIZELJ, A., WACHA, L., ŠIMIĆ-STANKOVIĆ, M., HEĆIMOVIĆ, Lj., TIBLJAŠ, D. & KRUK, B. (2006): Ivošević Gaj ceramic clay deposit in the vicinity of Vojnić. In: VLAHOVIĆ, I., TIBLJAŠ, D. & DURN, G. (eds.): 3rd Mid-European Clay Conference. 18-23. September, 2006, Opatija, Field Trip Guidebook, 39-47.

GRIZELJ, A., BAKRAČ, K., HORVAT, M., AVANIĆ, R. & HEĆIMOVIĆ, I. (2017): Occurrence of vivianite in alluvial Quaternary sediments in the area of Sesvete (Zagreb, Croatia). Geol Croat, 70, 41-52.

Clay Mineralogy and Properties of Soil and Underlying Plio-Quaternary Sediments of SE Mt. Medvednica (North Croatia)

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Plio-quaternary sediments of the southeastern part of Mt. Medvednica consist of colluvial and alluvial unconsolidated sediments (BASCH, 1983). They are covered with a thin and young soil profile. By investigating clay mineralogy of these profiles at different depths, we tried to gain more insight into weathering processes and pedogenesis.

Samples were collected at two locations: Oporovec at depths of 25, 40 and 70 cm and Dotrščina at depths of 25, 120 and 300 cm. Mineralogical composition of the bulk samples was determined using XRD on randomly oriented mounts. Clay minerals were analyzed further after the removal of organic matter, carbonates and Fe/Mn/Al oxides using XRD on oriented slides on <2 μm and <0.2 μm fractions, and FTIR-ATR on <2 μm and <0.2 μm fractions. Additionally, CEC was determined for bulk samples, before and after removal of organic matter, carbonates and Fe/Mn/Al oxides, and the share of Fe/Mn/Al oxides was determined after their removal with Tamm reagent.

The XRD results show the presence of quartz, plagioclase and some muscovite in the bulk samples in addition to clay minerals. Clay minerals in the samples include expandable clays, illite and kaolinite with some presence of mixed-layered clays detected. CEC values are much higher for untreated bulk samples, than samples from which organic matter, carbonates and Fe/Mn/Al oxides were removed. Samples contain a very low content of Fe/Mn/Al oxides (under 1%) with Mn being the least abundant. Slight decrease in their concentration is noticed in the underlying sediment compared to the soil horizons, probably due to Holocene weathering of minerals in the upper horizons (HUANG et al., 2011).

It is obvious that the mineralogy of the samples does not vary much with depth. Clay minerals present show slight variations between different fractions, e.g. 10 and 7 Å peaks are more prominent in <2 μm fraction which can be explained with larger crystallites of illite and kaolinite. This can be confirmed for kaolinite with FTIR-ATR results.

It could be concluded that the observed non-prominent variation in mineral composition within soil profiles developed on investigated plio-quaternary sediments might be related to an early stage of pedogenesis occurred on unconsolidated young sediments.

Keywords: *clay minerals, weathering, soil profile*

References

BASCH, O. (1983): Osnovna geološka karta SFRJ 1:100.000, Tumač za list Ivanić-Grad L33-81. [Basic Geological Map of Yugoslavia 1: 100.000, Commentary for sheet Ivanić-Grad L33-81 – in Croatian]. Geological Institute, Zagreb.

HUANG, C., ZHAO, W., LIU, F., TAN, W. & KOOPAL, L.K. (2011): Environmental significance of mineral weathering and pedogenesis of loess on the southernmost Loess Plateau, China. Geoderma, 163, 219-226.

Brackish Ostracods in Early/Middle Miocene and Holocene Lake Deposits; are Analogies Acceptable?

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Ostracods are small, bivalved crustaceans present in all aquatic and some terrestrial habitats. They are commonly preserved as fossils in sediments. In addition to ostracods ecological sensitivity to physical and chemical parameters, ostracods reflect the marine influence inside the paleolakes, and have great potential for the identification

and reconstruction of transitional palaeoenvironments. The occurrence of indicative species, their proportion within the whole assemblage and the composition of the assemblage provide the important data for the interpretation of past changes (FRENZEL & BOOMER, 2005).

This work studies the possible analogy between the brackish ostracods from Early/Middle Miocene lake deposits of Mt Požeška gora and ostracods from Holocene lacustrine deposits of the Adriatic coast. The aim of this study is to determine the changes in ostracod populations and occurrence and distribution of the first brackish ostracods by age and location of different paleolakes. According to GRIFFITHS & HOLMES (2000), post-Neogene ostracod assemblages/species can be compared with modern communities/taxa, allowing the understanding of ecological setting of past environments.

Occurrence of brackish environmental marker taxa: *Cyprideis torosa* (JONES) and *Cytheromorpha fuscata* (BRADY) in Holocene deposits and *Cyprideis sublittoralis* POKORNÝ, *Aurila* sp., *Leptocythere* sp. and *Amnicythere* sp. in Miocene deposits, associated with halophile freshwater species indicates the dominant water type formed by the mixing of marine and fresh water and the variability in salinity of the investigated paleolakes. Findings of the mentioned brackish taxa coincide with research results of FRENZEL & BOOMER (2005) who have distinguished four ecological groups of brackish ostracods based on their salinity tolerance.

There is no single formula or function which could be applied to all localities, but the exchange of marine and lacustrine palaeoenvironments in both Early/Middle Miocene deposits of Mt. Požeška gora and Holocene deposits of the Adriatic coast is in accordance with climate changes, sea level changes and tectonic movements of the local or regional scale.

Keywords: ostracoda, Croatia, paleolakes, transitional paleoenvironments

References

FRENZELl, P. & BOOMER, I. (2005): The use of ostracods from marginal-marine, brackish waters as bioindicators of environmental change and Quaternary palaeoenvironmental analysis e a review. Palaeogeogr. Palaeoclimatol. Palaeoecol., 225, 68-92.

GRIFFITHS, H.I. &. HOLMES, J.A. (2000): Non-marine ostracods and Quaternary palaeoenvironments. Quaternary Research Association, Technical Guide, 8, London: 188 p.

Submerged Paleolandscapes of Karst Rivers Zrmanja, Cetina, Neretva and Koločep in the Eastern Adriatic Coast (Croatia)

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During the Last Glacial Maximum (LGM) lowstand, large areas of the Adriatic shelf were exposed. At that time, relative sea level (RSL) was at least 125 m lower than present (FAIRBANKS, 1989; LAMBECK et al., 2011; BENJAMIN et al., 2017). This enabled formation of lakes, river valleys and their floodplains that were subsequently submerged during Holocene transgression (VACCHI et al., 2016; ANTONIOLI et al., 2009).

Here we present a study of karst paleorivers Zrmanja, Cetina, Neretva and Koločep located along the Eastern Adriatic Coast (Fig. 1). Well preserved submerged paleolandscapes are detected using high resolution acoustic geophysical methods (sub-bottom profiler) coupled with bathymetric data. Interpreted geophysical data are compared to RSL curve for the Adriatic region (BENJAMIN et al., 2017, LAMBECK et al., 2011).

Seismic data for paleo-Zrmanja River shows channels incised into Pleistocene clastic rocks exposed during the early Holocene. Larger valley flowing from present Karin Sea area into present Novigrad Sea area joined river Zrmanja and continued into Velebit Channel. Numerous channels detected in seismic profiles point to the existence of braided river system. Western part of the depression in today's Novigrad Sea hosted a small lake. As the RSL rose marine sediments overlie fluvial and terrestrial sediments at depth 35.7 m below sea level (b.s.l.), an event dated at

Figure 1. Locations of studied paleolandscapes located along the Eastern Adriatic Coast.

11440 BP (HASAN, 2017). As the RSL rose, it caused a gradual formation of 27 m thick alluvial fan in the present Zrmanja River mouth located at the exit of the canyon.

Present day floodplain of the Neretva River located at the river mouth extends landward over 10 km. Acoustic geophysical data shows similar floodplain formed approximately 60 km to the west, between islands Hvar, Šćedro and Korčula, at sea depth of 65–70 m b.s.l. Geological structures form acoustic basement of the sedimentary basin that predefined the accommodation space, as well as river path. Fluvial sediments with parallel to subparallel stratified reflectors onlap on the basin edges and overlie limestones. According to RSL curve (LAMBECK et al., 2011) fluvial sedimentation began approximately 13900 BP at 85 m b.s.l. After the basin was filled up to 70 m b.s.l., paleo-Neretva floodplain widened all the way to Korčula Island, creating a 10 km wide floodplain. Major erosional surface is visible, as Neretva River eroded its older fluvial sediments. Two meters of marine sediments overlie fluvial sediments.

Cetina river mouth is located at the exit from the canyon in the town of Omiš. Seismic data reveal that during the LGM river did not flow in NW direction as a continuation of today's flow but created a valley along the coast in SSE direction. In the postglacial period river eroded flysch sequences deposited on the steep hillslopes of Omiška Dinara mountain, and created over 15 m deep and 350 m wide river valley. Due to a Holocene RSL rise, channel was infilled with retrogradational fluvial sediments. Submerged bottom of the valley along Omiška Dinara mountain stands at 81 m b.s.l. Deposition of fluvial sediments started after 13800 BP (LAMBECK et al., 2011). As sediments gradually filled in the channel, Cetina created a 3 km wide floodplain. Thickness of fluvial sediment is 20 m. Fluvial sediments are overlain by 3-5 m thick marine sediment sequence.

Nine acoustic units (marine, lake or fluvial) can be recognized on the geophysical data recorded in the Kološep Channel. During the LGM lowstand intensive erosion occurred in the central part of the basin. Sediments were transported by torrents, whose springs still exist today as submarine springs at depths of 45–50 m b.s.l. Torrents joined and formed a river flowing through Veliki vratnik passage in SW direction towards Mljet Island, and continued along it's coastline towards the west. Eastern bank of the "Kološep" River was bounded by eolian sand bar. River ceased to exist as RSL rose to approximately 50 m b.s.l. Submerged valley between Pelješac and Mljet Islands is incised into sandy sediments and is well defined on bathymetry data.

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Keywords: *acoustic geophysical methods, submerged landscape, Holocene, Eastern Adriatic Coast*

References

ANTONIOLI, F., FERRANTI, L., FONTANA, A., AMOROSI, A., BONDESAN, A., BRAITENBERG, C., DUTTON, A., FONTOLAN, G., FURLANI, S., LAMBECK, K., MASTRONUZZI, G., MONACO, C, SPADA, G. & STOCCHI, P. (2009): Holocene relative sea-level changes and vertical movements along the Italian and Istrian coastlines. Quaternary International, 206, 102-133.

BENJAMIN, J., ROVERE, A., FONTANA, A., FURLANI, S., VACCHI, M., INGLIS, R.H., GALILI, E., ANTONIOLI, F., SIVAN, D., MIKO, S., MOURTZAS, N., FELJA, I., MEREDITH-WILLIAMS, M., GOODMAN-TCHERNOV, B., KOLAITI, E., ANZIDEI, M. & GEHRELS, R. (2017): Late Quaternary sea-level changes and early human societies in the central and eastern Mediterranean Basin: An interdisciplinary review. Quaternary International, 449, 29-57.

FAIRBANKS, R.G. (1989): A 17,000-year glacio-eustatic sea level record: influence of glacial melting rates on the Younger Dryas event and deep-ocean circulation. Nature, 342, 637-642.

HASAN, O. (2017): Paleookolišna rekonstrukcija slivova Karinskoga mora, Novigradskoga mora i Velebitskoga kanala tijekom holocena [Holocene palaeo-environmental reconstruction of the Karin Sea, Novigrad Sea and Velebit Channel catchments – in Croatian, with an English Abstract]. Unpubl. PhD Thesis, Faculty of mining, geology and petroleum engineering, University of Zagreb, 564 p.

LAMBECK, K., ANTONIOLI, F., ANZIDEI, M., FERRANTI, L., LEONI, G., SCICCHITANO, G. & SILENZI, S. (2011): Sea level change along the Italian coast during the Holocene and projections for the future. Quaternary Int., 232, 250-257.

VACCHI, M., MARRINER, N., MORHANGE, C., SPADA, G, FONTANA, A. & ROVERE, A. (2016): Multiproxy assessment of Holocene relative sea-level changes in the western Mediterranean: Sea-level variability and improvements in the definition of the isostatic signal. Earth-Science Reviews, 155, 172-197.

Magnetic Properties of Topsoils in Croatia

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Magnetic susceptibility (MS) of soils and paleosols indicates the formation of secondary ferrimagnetic minerals (SFM) and pedogenic processes. MS measurements can relatively fast and non-destructively characterize the concentration, mineralogy, and grain size of magnetic minerals present in samples (HATFIELD, 2014; PETERS & DEKKERS, 2003). The soil characteristics are influenced by variations in iron mineral forms, and it can give clue to the processes of pedogenesis (DEARING, 1996). Topsoil has been identified as an environment in which ferrimagnetic materials are actively produced. Secondary magnetic minerals (magnetite/maghemite) are mostly ultrafine grained and contain a significant superparamagnetic (SP) component (<0.03 μm).

The analysis of surface (0-10 cm depth) and sub-surface soils (20-30 cm depths) in a dataset created from more than 750 locations in Croatia (MIKO et al., 2017) have been performed through measurements of low field mass specific MS (Xlf), mass specific and frequency-dependent MS (Xfd). The aim of the study was to determine the spatial distribution of MS. The MS data set is combined with data for geochemistry, geology and soil type in order to determine the main source of magnetic particles. Data can then be used for provenance studies of soil and erosional processes (HATFIELD & MAHER, 2008), climate reconstructions (MAHER, 2011; GEISS et al., 2008) as well as evaluation of historical landuse and anthropogenic soil pollution (HOFFMANN et al., 1999; MITCHELL et al., 2010). Measurements are also used in the landmine-affected regions because of the effect of soil MS on metal detectors (HANNAM & DEARING, 2008).

Maps created with the soil MS data set in Croatia show two clearly differentiated distributions – Pannonian region versus Dinaric area of Croatia (Fig. 1). Differences exist due to the geological sub-division of Croatia and its associated main soil types: the Mesozoic carbonate rocks of the Dinaric-Coastal karstic region with dominant red soils and calcocambisols versus the Pannonian region with dominant cambisols, luvisols and gleysols mostly developed on clastic Neogene and Quaternary sediments (HGI, 2009, BOGUNOVIĆ et al., 1996). Summary data shows that soils developed on carbonate rocks have higher MS values compared to soils of the Pannonian region (Fig. 1). Anthrosols also have elevated MS values.

Magnetic properties of soils in the karstic area are dominated by the presence of nanoscale SP SFM grains produced in situ. Soil-derived magnetite gives major contribution to the magnetic enhancement in red soils. Primary ferrimagnetic minerals derived from geological sources dominate magnetic properties in only a minority of localities (mountainous areas composed of magmatic and metamorphic rocks).

This is the first attempt to produce a soil magnetic susceptibility map of Croatia that covers all dominant soil types in Croatia.

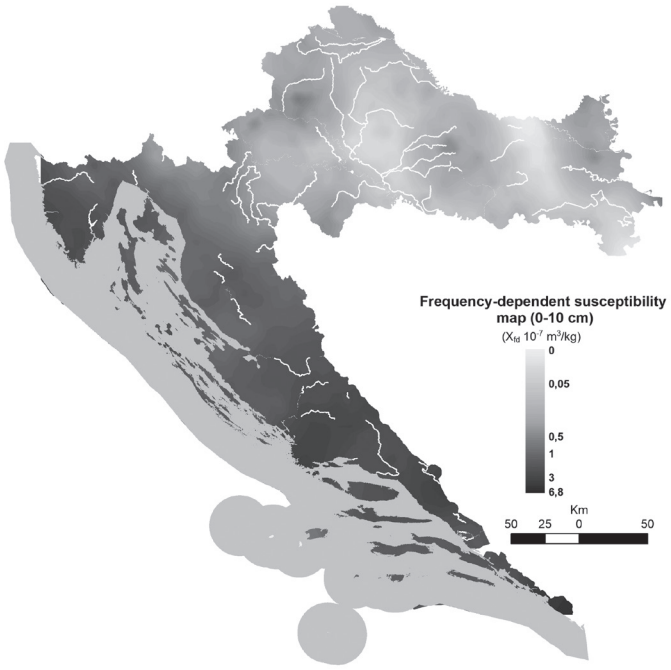

Figure 1. Interpolated Frequency Dependant Susceptibility Map of Soils (X_{fd} (10^{-7} m^3kg^{-1})) in depth interval 0 to 10 cm. Soils from the Dinaric-coastal region, especially terra rossa soils, have elevated magnetic susceptibility values compared to the Pannonian region.

Acknowledgements

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Keywords: *magnetic susceptibility, Croatian topsoil, ferromagnetic minerals, karst, pedogenesis*

References

BOGUNOVIĆ, M., VIDAČEK, Ž., RACZ, Z., HUSNJAK, S. & SRAKA, M. (1996): Namjenska pedološka karta tala za obradu Republike Hrvatske M 1:300.000.

DEARING, J.A., HAY, K.L., BABAN, S.M.J., HUDDLESTON, A.S., WELLINGTON E.M.H. & LOVELAND, P.J. (1996): Magnetic susceptibility of soil: an evaluation of conflicting theories using a national data set. Geophys. J. Int., 127,728-734.

GEISS, C.E., EGLI, R. & ZANNER, C.W. (2008): Direct estimates of pedogenic magnetite as a tool to reconstruct past climates from buried soils. J. Geophys. Res., 113, 1-15.

HANNAM J.A. & DEARING, J.A. (2008): Mapping soil magnetic properties in Bosnia and Herzegovina for landmine clearance operations Earth and Planetary Science Letters, 274, 285-294.

HATFIELD, R.G. (2014): Particle Size-Specific Magnetic Measurements as a Tool for Enhancing Our Understanding of the Bulk Magnetic Properties of Sediments. Minerals, 4, 758-787.

HATFIELD, R.G. & MAHER, B.A. (2018): Suspended sediment characterization and tracing using a magnetic fingerprinting technique: Bassenthwaite Lake, Cumbria, UK. Holocene, 18, 105-115.

HOFFMANN, V., KNAB, M. & APPEL, E. (1999): Magnetic susceptibility mapping of roadside pollution. J. Geochem. Explor., 66, 313-326.

HRVATSKI GEOLOŠKI INSTITUT, HGI (2009): Geološka karta Republike Hrvatske 1:300.000. Hrvatski geološki institut, Zagreb.

MAHER, B.A. (2011): The magnetic properties of Quaternary Aeolian dusts and sediments, and their palaeoclimatic significance, Aeolian Research, 3/2, 87-144.

MIKO, S., HASAN, O., KOMESAROVIĆ, B., ILIJANIĆ, N., ŠPARICA MIKO, M., ĐUMBIR, A.M., OSTROGOVIĆ SEVER, M.Z., PALADINIĆ, E. & MARJANOVIĆ, H. (2017): Promjena zaliha ugljika u tlu i izračun trendova ukupnog dušika i organskog ugljika u tlu te odnosa C:N. Knjiga I: Izvješće o setu podataka za izradu izvješća prema Okvirnoj konvenciji UN-a o promjeni klime – UNFCCC (sektori LULUCF i poljoprivreda).

MITCHELL, R., MAHER, B.A. & KINNERSLEY, R. (2010): Rates of particulate pollution deposition onto leaf surfaces: Temporal and inter-species analyses. Environ. Pollut. 2010, 158, 1472-1478.

PETERS, C. & DEKKERS, M.J. (2003): Selected room temperature magnetic parameters as a function of mineralogy, concentration and grain size. Phys. Chem. Earth, 28, 659-667.

Jankovac-Koprivnički Bregi 2D – From Seismic Acquisition to Final Image

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INA as operator on the Drava-02 License performs exploration activities aiming to explore/find new hydrocarbon reserves. Previous 2D seismic in that area is of insufficient quality and low resolution because of older year of recording and complex tectonics, therefore it was necessary to acquire a new seismic. The Jankovac-Koprivnicki Bregi 2D project was located in the western part of exploration License Drava-02. The project was acquired by Geofizyka Toruń S.A. and lasted from 19th October till 14th December 2018 with the total of 30 2D lines (389 km) recorded. The position of seismic lines can be seen in Fig. 1. The project stretched over the heavily populated area comprising of 2 counties, 13 townships, and 37 villages, requiring cooperation with 20 state and local institutions plus 21 hunting associations. To successfully organize and implement such a complex project joint efforts of INA and selected seismic service company were made in direction of including and sensitizing local community. Complex technical requirements were met by phasing the project into two complementary programs (A&B). Acquisition parameters were designed specifically for each program which was an innovative solution and it made possible to target deep (Program A) and shallow (Program B) objects on each program. Program B area was very demanding because it is hilly and covered mostly by forests with limited access. Because of that, it was often necessary to use shortened or

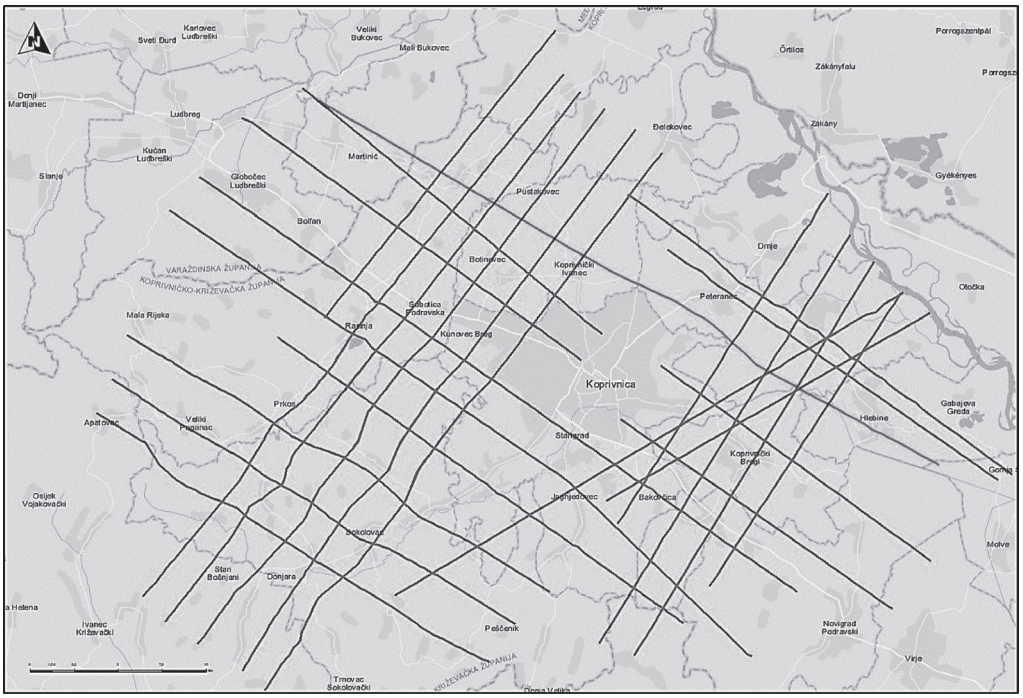

Figure 1. Position of 2D lines.

even bunched array for receiver points. Terrain on program A was slightly different than on program B. Most of program A area was flat and covered by fields, villages and small towns which caused part of the source and receiver points to be stacked out on the shifted position or skipped due to a safety distances. Compared with the older 2D seismic campaigns main acquisition parameters were significantly improved (receiver and source point interval, number of active channels, maximum offset, sweep types) which drastically increased nominal fold and quality of acquired data. The acquisition was completed without any HSE incidents which additionally strengthened reputation of INA as a company that nurtures outstanding relations, appreciates involvement of local people and operates under the principles of sustainable development.

Seismic data processing commenced at the beginning of January and the data was delivered to seismic interpretation at the beginning of April 2019. Processing has been carried out by INA-Processing Center, using WesternGeco's Omega2™ Seismic Processing System. Processing of seismic data from field tapes to final product included: geometry preparing and QC, noise analysis and suppression, deconvolution, velocity analysis, refraction and residual static correction, pre-stack time migrations, post-migration processing. The major challenges during the processing were matching of different seismic sources, unfavourable signal to noise ratio and long wavelength statics solution. New acquired seismic provided superior illumination and image of the subsurface compared with the older generation of 2D lines with better image in low S/N ratio areas, superior image in deeper parts and higher vertical and spatial resolution. New seismic will certainly help in reducing the exploration risk providing better insight into next exploration targets in Drava-02 exploration area. This campaign proved that new modern 2D seismic, considering all limitation of 2D technique, can provide good insight into targeted area.

Keywords: *acquisition, processing, 2D seismic data*

Paleoecology and Paleoenvironment of the Upper Karpatian –Lower Badenian Sedimentary Succession from SE Medvednica Mt., Croatia

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The Miocene sediments of the Northern Croatia belongs to the SW margin of the Central Paratethys (Pannonian Basin System). Beside the Lower Badenian sediments of the Plaz locality near village Čučerje (SE Medvednica Mt.) described previously by AVANIĆ et al. (1995) and ĆORIĆ et al. (2009), approximately 50 m thick Upper Karpatian to Lower Badenian underlying succession along the Bokanjščica stream has been also studied.

Upper Karpatian (Bokanjščica stream): The lowermost part of marine sedimentary succession consists mostly of fossiliferous calcareous mudrocks (marls) deposited on the deeper shelf and in the offshore-transition zone, below the fair-weather wave base. According to calcareous nannoplankton, *Helicolith* horizon (NN4 Zone) have been determined. The last appearance datum (LAD) of *Helicosphaera ampliamperta* is noticed in sample where *Sphenolithus heteromorphus Paracme* ends that represents a very useful correlation tool defining the Subzone MNN4b. Planktonic foraminiferal assemblage consists of numerous specimens of the cool surface water indicators such as *Tenuitella angustiumbilicata* and *Globigerinita glutinata*. Frequent occurrence of infaunal benthic foraminifera such as *Bulimina*, *Bolivina* and *Nonion* indicate low oxygen but organic carbon reach sea bottom.

Lower Badenian (Bokanjščica stream): The middle part of marine sedimentary succession consists of fossiliferous calcareous mudrock deposited on the deeper shelf environment. On the basis of calcareous nannoplankton Lower Badenian *Helicosphaera waltrans* horizon (NN5 Zone) is determined. The regular occurrence of *Sphenolithus heteromorphus*, together with close records of *Helicosphaera waltrans* upwards, corresponds to the Mediterranean Subzone MNN5a. Sediments contain reach and highly diversified calcareous benthic foraminiferal assemblage dominated by infaunal organic carbon-preferring genera such as *Bulimina*, and low-oxygen adapted taxa like *Bolivina*, *Uvigerina* and *Pappina* indicating middle shelf environment. First occurrence of the shallow and warm-water preferring genera like *Elphidium*, *Glabratella* and *Pararotalia* have also been detected. Planktonic foraminiferal association is characterized by cool water taxa (*Tenuitella* spp., *Turborotalita quinqueloba*; 10%) and also by abundant presence of surface warm-water species *Cassigerinella chipolensis* (50%). The Lower Badenian ostracod fauna is dominated by deep marine species (*Cytherella compressa, Cytherella* aff. *vandenboldi, Henryhowella asperrima, Parakrithe dactylomorpha, Krithe* sp., *Krithe* cf. *monosteracensis, Cardobairdia* sp. and *Argilloecia acuminate*). A few valves of the shallow-water species (*Costa edwardsi, Loxocorniculum* cf. *hastatum, Loxoconcha* sp., *Grinioneis haidingeri*) are also present. Discovery of very rare Indo-Pacific species *Paijenborchella iocosa* indicates the establishment of connections between the Paratethys Sea, Mediterranean realm and Indo-Pacific Ocean. Palynological analyses show relatively abundant dinocyst association (*Systematophora placacantha, Melitasphaeridium choanophorum*). All these facts indicate sedimentation in marine somewhat deeper and distal environment.

Lower Badenian (Plaz section): The upper part of the Plaz section predominantly consists of calcareous mudrocks which are intercalated with layers of sandstones. The upper part of the profile is predominantly composed of sandstones and to a lesser extent of calcareous mudrocks, with tuffs on the top. It is a coarsening-upward succession indicating shallowing of the marine environment. Sediments contain shallow and warm water preferring benthic foraminifera (*Elphidium, Asterigerinata, Ammonia* and *Amphistegina*), whereas planktonic foraminifera are absent or very rare. Echinoderms, bryozoans and molluscan carbonate shell fragments are also present. Palynofacies is composed of diverse association of spores, pollen grains, foraminiferal test linings, dinocysts and fragments of colonial green alga *Botryococcus braunii* and dinocysts (*Operculodinium centrocarpum, Hystrichosphaeropsis obscura*, *Hystrichokolpoma rigaudiae*, *Melitasphaeridium choanophorum*) which indicate Badenian age and sedimentation in marine but somewhat shallower and more proximal environment in reach of terrestrial input.

The upper Karpathian sediments of the investigated secctions correspond to the Mi2 cooling event that induced climate instability and larger temperature oscilations. During Early Badenian warmer climate and MMCO was reestablished, but with more fluctuating environment.

Keywords: *Upper Karpatian-Lower Badenian, biostratigraphy, lithology, paleoecology, paleoenvironment*

References

AVANIĆ, R., PAVELIĆ, D., MIKNIĆ, M., BRKIĆ, M. & ŠIMUNIĆ, A. (1995): Karpatian-Lower Badenian beds from Čučerje. In: ŠIKIĆ, K. (ed.): Geological Guide of Mt. Medvednica. Inst. za geol. istraž. INA-Industrija nafte d.d., Zagreb, 156-158.

ĆORIĆ, S., PAVELIĆ, D., RÖGL, F., MANDIC, O., VRABAC, S., AVANIĆ, R. & VRANJKOVIĆ, A. (2009): Revised Middle Miocene datum for initial marine flooding of North Croatian Basins (Pannonian Basin System, Central Paratethys). Geol. Croat., 62, 31-43.

Jurassic Play, Western Desert

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The main goal of this paper is to define and explain the Jurassic play of Western Desert. The Western desert comprises the area west of the Nile River and south of the Mediterranean Sea covers an area of about 200,000 km^2 and includes sedimentary sections locally in excess of 7000 m. Today the Western Desert is the most important hydrocarbon producing area in Egypt (BOSWORTH et al., 2015), producing both gas and oil from 399 fields. Major basins are the Abu Gharadig, Alamein, Natrun, Matruh and Shushan basin. At least 12 major tectonostratigraphic events control a multitude of trapping styles and petroleum systems (DOLSON et al., 2014).

Regarding Jurassic petroleum system, the Western Desert geological hydrocarbon province comprise a thick mature source rock of the Middle Jurassic Khatatba Formation. It has very good intervals of organic richness (TOC 1.3 wt. % (avg) – 2.1 wt. % (max)) and is mixed oil and gas-prone (Type II and III kerogen) in the upper section and becomes more gas-prone in the lower section. The lithologies and depositional environments of the Khatatba Formation vary laterally from predominantly fluvial and estuarine in the south to progressively more marine in the north. The southern fluvial facies are often associated with both coals and organic-rich shales that tend to be oil-prone (LUCIC & BOSWORTH, 2019) while northern Western Desert Khatatba source rocks can be more gas-prone (SHALABY et al., 2012). In the South Alamein area, maturation began where the organic-rich sediments were most deeply buried at the end of the Cretaceous but hydrocarbon migration didn't start before the deposition of the Apollonia Formation at about 40 Ma (MORETTI et al., 2010). The Khatatba Formation itself also contains good quality siliciclastic reservoirs assigned to the Safa Member, and is, therefore, a complete petroleum system on its own. The interplay of the resulting east–west and NW–SE striking extensional faults have a dominant role in controlling the development of structural plays and migration pathways out of the mature source rock depocenters (LUCIC & BOSWORTH, 2019). Structural traps are predominate in relations to stratigraphic traps. Other reservoirs sourced by Jurassic are the main syn-rift strata of the Early Cretaceous Burg el Arab Formation (Alam el Bueib and Kharita Members) and the overlying Bahariya Formation. Top and lateral seal rocks are Masajid carbonate rocks and Upper Khatatba shales.

The review of geological setting of Jurassic play is presented through regional mapping, geochemical and seismic data.

Keywords: *Jurassic, play, Western Desert, petroleum system, geology*

References

BOSWORTH, W., ABRAMS, M.A., DRUMMOND, M. & THOMPSON, M. (2015): Jurassic rift initiation source rock in the Western Desert, Egypt – relevance to exploration in other continental rift systems. Proceeding 34th Annu. GCSSEPM Found. Bob F. Perkins Res. Conf. Pet. Syst. "rift" basins, 615-650.

DOLSON, J.C., ATTA, M., BLANCHARD, D., SEHIM, A., VILLINSKI, J., LOUTIT, T. & ROMINE, K. (2014): Egypt's Future Petroleum Resources: A Revised Look into the 21st century, In: MARLOW, L., KENDALL, C.C.G. & YOSE, L.A. (eds.): "Petroleum Systems of the Tethyan Region", AAPG Memoir, no. 106, 143-178.

LUCIC, D. & BOSWORTH, W. (2019): Regional Geology and Petroleum Systems of the Main Reservoirs and Source Rocks of North Africa and the Middle East. In: BENDAOUD, A. et al. (eds.): The Geology of the Arab World – An Overview, Springer Geology. https://doi.org/10.1007/978-3-319-96794-3_6.

MORETTI, I., KERDRAON, Y., RODRIGO, G., HUERTA, F., GRISO, J.J., SAMI, M., SAID, M. & ALI, H. (2010): South Alamein petroleum system (Western Desert, Egypt). Petroleum Geoscience, 16 (2), 121-132.

SHALABY, M.R., HAKIMI, M.H. & ABDULLAH, W.H. (2012): Organic geochemical characteristics and interpreted depositional environment of the Khatatba formation, northern Western Desert, Egypt. AAPG Bull, 96, 2019-2036.

Reconstruction of the Sarmatian Paleoenvironments Based on Benthic Foraminifera, Case Study: Bukova Glava Section

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The section Bukova glava, located within the quarry Našicecement d.d., on the northern slope of Krndija Mt., belongs to the North Croatian Basin. During the Middle Miocene, the basin situated on the southwestern margin of the Central Paratethys Sea, was a part of Pannonian Basin System (PAVELIĆ & KOVAČIĆ, 2018). Previous studies revealed the continuity of sedimentation from the Badenian to Sarmatian (KOVAČIĆ et al., 2015; KOVAČIĆ et al., 2017). The Upper Badenian *Bulimina – Bolivina* was identified in the section based on smaller benthic foraminifera, whereas the top of the section was attributed to the *Anomalinoides dividens* zone of the Lower Sarmatian. Due to recent work in quarry, the upper part of the sections became available for study and consequently high-resolution sampling and logging took place in April 2019. This abstract contains preliminary results of study of smaller benthic foraminifera from newly exposed dark and light marly beds. Samples submitted standard treatment in laboratory (wet sieving and standardization into aliquots of about 300 specimens per sieve-residue). The analysis included quantification of planktonic vs benthic foraminifera (P/B ratio), generic interpretation of benthics and study of taphonomic conditions of foraminiferal tests. All studied tests are well preserved. The low values of P/B ratio are characteristic for shallow-water settings, inner shelf zone, whereas greater values of the ratio, found in some parts of the section, suggest possible deepening of the Sarmatian paleoenvironment. Two foraminiferal assemblages were described, *Elphidium* assemblage confined to the light marls and *Bolivina* assemblage to the dark beds. *Elphidium* assemblage is composed of large individuals of epifaunal forms among which representatives of *Elphidium* sp. with well-developed keel prevail. These characteristics suggest an oxic environment, with phytal covers where herbivores thrived (according to MURRAY, 2006). The dark marly samples depict that changes in the environments took place. The *Bolivina* assemblage is made of smaller individuals where *Bolivina* representatives dominate. Infaunal mode of life, dysoxic conditions (MURRAY, 2006) and detritus feeders are characteristics of bolivinas, implying possible reduction in oxygen concertation. The local sea-level changes or changes in terrigeous input caused by different rate of weathering could provoked such alteration of foraminiferal assemblages.

Keywords: *Elphidium* sp., *Bolivina* sp., *Sarmatian, Central Paratethys, Bukova Glava*

References

KOVAČIĆ, M., VRSALJKO, D., PEZELJ, Đ., PREMEC FUĆEK, V., HERNITZ KUČENJAK, M., GALOVIĆ, I., ĆORIĆ, S., ZALOVIĆ, M. & MARKOVIĆ, F. (2017): A Middle Miocene Marine Deposition with Pyroclastics. In: KOVAČIĆ, M., WACHA, L. & HORVAT, M. (eds.): Neogene of Central and South-Eastern Europe, Field Trip Guidebook, Croatian Geological Society, Zagreb, 19-21.

KOVAČIĆ, M., ĆORIĆ, S., MARKOVIĆ, F., PEZELJ, Đ., VRSALJKO, D., BAKRAČ, K., HAJEK-TADESSE, V., BOŠNJAK MAKOVEC, M., RITOSA, A. & BORTEK, Ž. (2015): Carbonate and clastic sediments of Upper and Middle Miocen (Našice quarry). In: HORVAT, M. & GALOVIĆ L. (eds.): 5th. Croatian Geological Congress, Excursion Guide-book, Croatian Geological Survey, Zagreb, 82-85.

MURRAY, J.W. (2006): Ecology and applications of benthic foraminifera. Cambridge University Press, Cambridge, 1-438.

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.

Paleolake in Bribir-Ostrovica Karst Polje in Dalmatia

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The Bribir-Ostrovica karst polje is one of a series of karst poljes in Ravni Kotari region in Dalmatia filled with lake sediments. They are surrounded with Cretaceous and Paleogene carbonate rocks and Eocene flysch. The central parts of the poljes are filled with Quaternary lake sediments, while the edges are covered with colluvial and alluvial sediments (sands and pebbles). The distribution of lake sediments in the Bribir-Ostrovica polje was analyzed based of geomorphological characteristic of the polje and the analysis of the undisturbed lake sediment sequences at three sites. Lake sediments contain a record of past environmental changes. Lake sedimentation depends on the surface water inflow and terrigenous material input from the surrounding basin, and climatic conditions. Lake sediments are used in archaeological studies for the reconstruction of a paleoenvironment of the area and in recent times are used in geoacrheology. The lake sediments indirectly point to the environmental changes that took place near archeological sites that could have had an impact on the movement of people in the past. Paleolimological study involve a multi-proxy approach through sedimentological, mineralogical, geochemical and micropaleontological analysis of lake sediment core. The OSP-3 sediment core contains lake sediments in a total length of 472 cm, spanning to 13200 years BC. During this period, in the Bribir-Ostrovica polje the lake-wetland environment was developed and thus during the Neolithic period (6000-4000 years BC).

The Neolithic settlement in Krivače archaeological site existed near the lake environment. Changes in sedimentation of lake carbonates and siliciclastic material point to a dynamic environment and changes in climatic conditions. Lake carbonate sedimentation is characterized by the deposition of endogenic calcite from the water column due to favorable biochemical conditions of lake water. It is indicative for a warm climatic conditions and a deeper lake environment, recorded in the period from 10000 to 8000 BC. The ostracod assemblages points to a dynamic, shallow environment under the influence of erosional processes and cold climatic conditions in older lakes sediments. It gradually decreases and converts into assemblage typical for shallow lakes and wetlands in younger lake sediments. Based on the geomorphologic characteristic of the polje and the analysis of lake sediment core, the paleolake in the Bribir-Ostrovica polje could not be deeper than 6 m. The thickest lake sediments are assumed in the geomorphologically lowest part of the terrain, west of Mount Školj, in the area that floods in wet periods at present times. Proximal parts of the polje, as well as the area within the archaeological site of Krivače, contain alluvial and colluvial sediments, deposited by streams that created a system of pools within the tufa barriers. Lake as a permanent water body could not be developed in the polje south of the Brbišnica River, west of Brbirske Mostine, due to higher elevation and slope relief. More likely, a cascade of smaller periodical lakes/ponds were formed separated by tufa barriers and flowing water.

Paleolimnological study of lake sediments in the Bribir-Ostrovica polje can indirectly point to the paleoenvironment that prevailed in the period when Neolithic site in Krivače was inhabited.

Acknowledgements

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Keywords: *paleolimnology, Dinaric karst, lake sediments, paleoenvironment, geomorphology*

Preliminary Paleolimnological and Geomorphological Research of the Prološko Blato Area in Imotsko Polje

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The Prološko Blato area is seasonally flooded, north-western part of the Imotsko polje (karst polje) situated in the central part of Dinaric karst. It is made of Quaternary lacustrine sedimentary sequence surrounded by Cretaceous carbonates. Fluctuating water level turns the environment from wetland to grassland. This transition represents a period of erosion and formation of distinctive erosional channels, which are then suitable for mapping and sampling of sediments. The eastern part of the Prološko Blato called Prološko Lake, is according to BONACCI & ROJE-BONACCI (2000) an estavelle. This is a typical Dinaric karst landscape that contains numerous geomorphological features: springs, streams, and dolines. Later ones seem to be the most significant in the context of climate change and environmental protection of this remarkable karst phenomenon.

The preliminary field research included: core drilling, sediments sampling, side-scan sonar measuring, and digital photogrammetry by ShapeMetriX3D (3G SOFTWARE & MEASUREMENT GMBH, 2007). Laboratory work included: high-resolution core analysis, radiocarbon dating, geochemical, mineralogical and grain-size analysis, as well as micropaleontological analysis of ostracods. Additionally, geomorphological analysis of the Prološko blato, its catchment area, and surrounding dolines was conducted using various spatial input data.

The lacustrine sequence is about 7 meters (or more) thick and divided into lacustrine deposits with alluvial influence at the bottom and carbonate deposits with clays at the top. Carbonate deposits belong to the Holocene and can be characterized as lacustrine chalk that started to form approximately 9 600 cal yr. BP. It is rich in calcium and well-preserved fossils of ostracods, gastropods, and charophytes. The lower part of the Holocene section is a dark siliciclastic mud determined as black and brown clays with great lateral continuity. Their formation is related to strong erosional input, evident in the significant increase of magnetic susceptibility, higher content of siliciclastic elements and lack of ostracods. They were forming between 11 250 and 9 600 cal yr. BP. Beneath the clays come lacustrine deposits with clear alluvial influence belonging to the period of intensive erosion and deposition of poorly sorted sands and silts, with numerous gravel lenses defined as alluvial paleochannels. It is presumed that alluvial deposits belong to the Late Pleistocene period. These are followed by the thick bluish-gray clay, again rich in ostracods.

The Prološko Blato can be divided into the paleolake in the western, and modern lake in the eastern part. Its central basin was probably in the western part, evident in the absence of alluvial paleochannels and increasing thickness of lacustrine sediments. The Prološko Lake is categorized as a collapse type of doline (FORD & WILLIAMS, 2007) filled with water, i.e. karst lake, having a steep north-eastern sidewall with characteristic red to orange color. Its formation may be related to the strong tectonic activity of the area (DRAGIČEVIĆ et al., 1999), combined with the dissolution processes. Existence of a paleolake with the constant water level was presumably disrupted by the collapse of Prološko doline. This event may have been crucial in the development of the present hydrogeological system and can be used for future predictions, giving the fact that dolines are still forming both in lowland and highland part of the Imotsko polje, particularly subsidence type of dolines (FORD & WILLIAMS, 2007; MARŠIĆ, 2011). These hypotheses will be investigated with more detailed digital photogrammetry and core drilling. For further understanding of the underground karst features and paleolake extent, geophysical methods (electrical resistivity tomography, georadar, and multibeam sonar) will be of great importance.

Keywords: *Dinaric karst, karst lake, paleolake, paleolimnology, geomorphology*

References

BONACCI, O. & ROJE-BONACCI, T. (2000): Interpretation of groundwater level monitoring results in karst aquifers: examples from the Dinaric karst. Hydrological Processes, 14, 2423-2438.

DRAGIČEVIĆ, I., PRELOGOVIĆ, E., KUK, V. & BULJAN, R. (1999): Recent Tectonic Activity in the Imotsko Polje Area, Geologica Croatica, 52/2, 191-196.

FORD, D. & WILLIAMS, P. (2007): Karst Hydrogeology and Geomorphology. John Wiley and Sons, Chichester, 562 p.

MARŠIĆ, M. (2011): Geomorphological analysis of dolines of the wider area of Imotsko polje. Unpupl. Master Thesis, Faculty of Science, Univesity of Zagreb, Zagreb, 64 p.

3G SOFTWARE & MEASUREMENT GMBH (2007): ShapeMetriX 3D – 3D imaging for measuring and assessing rock and terrain surface. User Manual for Version 2, Graz.

"Čizlakite" – Quartz Monzodiorite from Slovenia

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In the southeastern part of the Pohorje Mts. (Slovenia) a small satellite magmatic body of special composition is outcropping within a larger granodiorite intrusion. It is a medium to coarse grained plutonic igneous rock locally known as "čizlakite" due to proximity of the village Cezlak. According to Streckeisen classification, it corresponds to the field uniting quartz monzodiorite and quartz monzogabbro. The aim of the research is to define to which rock type it corresponds.

The rock is one of a kind and macroscopically variegated due to its intense green and bright colours. The rock is crosscut by numerous white aplitic and pegmatitic veins in different orientations. It´s appearance, good quality and rarity make it very appreciated as a natural stone. Therefore, the rock is typical for Slovenia and it has been often used as a building or decorative stone in the important and protocol national buildings.

Rock samples were analysed by optical microscopy in plane polarized transmitted light, electron probe microanalysis (EPMA) with wavelength-dispersive x-ray spectrometry (WDS), and inductively coupled plasma mass spectrometry (ICP-MS).

The rock is holocrystalline. Poikilitic texture composed of plagioclases containing smaller clinopyroxenes or biotites is often observed. The mineral composition is variable with dark green amphibole and light green pyroxene, with minor plagioclase, biotite, K-feldspar and quartz. The most abundant is clinopyroxene with diopsidic composition (average 4.06 wt% FeO, 15.31 wt% MgO and 24.5 wt% CaO). Two generations of amphibole can be observed. The older generation with smaller and more altered grains corresponds to pargasite, edenite, ferro-hornblende and magnesio-hornblende. The younger generation of amphibole, characterised by magnesio-hornblende and actinolite, is replacing the clinopyroxenes and often exhibits uralitic texture. Plagioclases with andesine to oligoclase compositions dominate. Polysynthetic twins and zoned crystals are common. Potassium feldspars with elevated sodium content can also be detected. Dark mica can be found as an inclusion in amphiboles or as individual grains. Small grains of quartz occur in mirmekitic textures with plagioclase. Titanite, apatite and epidote, which is frequently enriched in REE, are main accessory minerals. In intensively differentiated and/or metasomatically altered samples clinopyroxene is almost completely replaced by amphibole and plagioclase with K-feldspar. Among secondary minerals chlorite and calcite are recognized. The formation of the rock is very complex and still not completely understood.

According to established mineral and chemical composition we recommend naming the rock quartz monzodiorite.

Keywords: *quartz monzodiorite, mineralogy, Pohorje Mts.*

Evolution of Ore-Bearing Fluids in the Cu-Au Porphyry Ore Body Vrshnik, the Buchim Deposit, Republic of North Macedonia

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The Buchim porphyry Cu-Au deposit (41.7° N, 22.3° E) is located in the contact zone between the Serbo-Macedonian Massif and the Vardar Zone approximately 90 km south-east from Skopje, Republic of North Macedonia. The total ore reserves have been estimated at 120 million metric tons with 0.3 % Cu and 0.3-0.5 g/t Au (SERAFI-

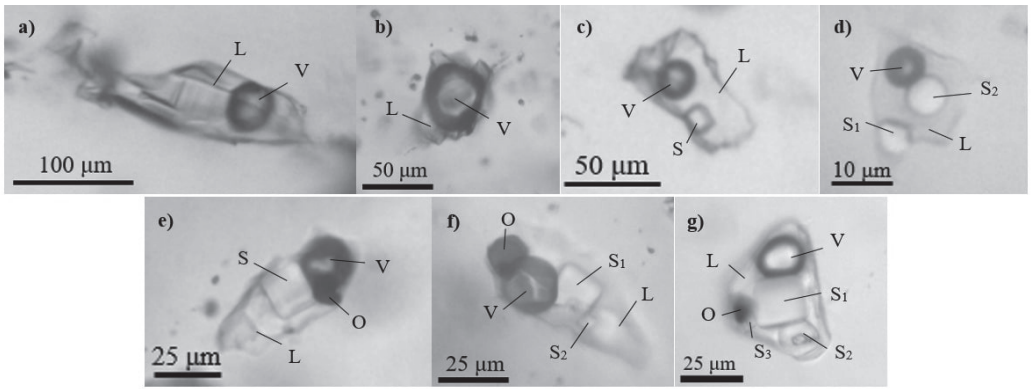

Figure 1. Types of fluid inclusions in quartz from the Buchim deposit: (a) Two-phase, L-rich inclusions (L+V) with the degree of fill around 0.8,; (b) Two-phase, V-rich inclusions (V+L) with the degree of fill around 0.2; (c) Three-phase inclusions that consist of liquid, vapor and a transparent isotropic solid phase (L+V+S); (d) Four-phase inclusions that consist of liquid, vapor and two transparent isotropic solid phases (L+V+S_1+S_2); (e) Four-phase inclusions that contain liquid, vapor, a transparent isotropic solid phase and an opaque solid phase (L+V+S+O); (f) Polyphase inclusions with liquid, vapor, two transparent isotropic solids and an opaque solid phase (L+V+S_1+S_2+O); and (g) Polyphase inclusions with liquid, vapor, two transparent isotropic solids, a transparent anisotropic solid phase and an opaque solid phase (L+V+S_1+S_2+ S_3+O). L stands for liquid, V for vapor, S for transparent solid and O for opaque phase.

MOVSKI et al., 2016). The mineralization is spatially and temporary related to subvolcanic intrusions of the latitic and latitic-andesitic composition that intruded Precambrian gneisses, mica-schists and amphibolites. The U–Pb zircon dating yielded the intrusion age between 24.19 ± 0.62 Ma and 24.51 ± 0.89 Ma (LEHMANN et al., 2013). The Buchim Cu deposit hosts 4 ore bodies: 1. Vrshnik; 2. Bunardzik; 3. Central ore body and 4. Chukar. Field data show a clear relationship that the Vrsnik intrusion is younger than the Central ore body and Bunardzik. The mineralization occurs as disseminations and in forms of stockworks predominantly hosted by the gneisses along their contacts with the Oligocene intrusions. The Vrshnik ore body represents an exception, with ore mineralization predominantly hosted by the intrusion. The main ore mineral is chalcopyrite accompanied with variable amounts of pyrite, magnetite, hematite, cubanite, bornite, native gold and quartz.

The ongoing fluid inclusion study revealed that syn-ore quartz may host several generations of fluid inclusions indicating a complex evolution of hydrothermal fluids in the Buchim Cu-Au porphyry deposit. According to their petrographic characteristics at room temperature (Fig. 1), the following types of fluid inclusions have been recognized: Type 1) Two-phase, L-rich inclusions (L+V) with the degree of fill around 0.8,; Type 2) Two-phase, V-rich inclusions (V+L) with the degree of fill around 0.2; Type 3) Three-phase inclusions that consist of liquid, vapor and a transparent isotropic solid phase (L+V+S); Type 4) Four-phase inclusions that consist of liquid, vapor and two transparent isotropic solid phases (L+V+S_1+S_2); Type 5) Four-phase inclusions that contain liquid, vapor, a transparent isotropic solid phase and an opaque solid phase (L+V+S+O); Type 6) Polyphase inclusions with liquid, vapor, two transparent isotropic solids and an opaque solid phase (L+V+S_1+S_2+O); and Type 7) Polyphase inclusions with liquid, vapor, two transparent isotropic solids, a transparent anisotropic solid phase and an opaque solid phase (L+V+S_1+S_2+ S_3+O), where L stands for liquid, V for vapor, S for transparent solid and O for opaque phase. The inclusions with opaque minerals (Types 5-7) have been interpreted as remains of ore-forming fluids. They are characterized by high homogenization temperatures (380-680 °C) and high salinities (26.9-74 wt.% NaCl equiv.). A broad range of homogenization temperatures and salinities indicates that mixing with colder and diluted fluids affected deposition of the Cu-Au mineralization. The main ore-forming phase was followed with several barren hydrothermal overprints (Types 1-4). Comparing to the ore-bearing inclusions, the homogenization temperatures of the barren L+V+S inclusions are somewhat lower (260-600 °C) as well as their salinities (30.8-54.5 wt.% NaCl equiv.). The L+V inclusions are characterized by the lowest recorded temperatures of homogenization (218-420 °C) and salinities (6.5-29 wt.% NaCl equiv).

Keywords: fluid inclusion, quartz, Buchim, ore deposit, porphyry

References

LEHMANN, ST., BARCIKOWSKI, J., VON QUADT, A., GALLHOFER, D., PEYTCHEVA, I., HEINRICH, C.A. & SERAFIMOVSKI, T. (2013): Geochronology, geochemistry and isotope tracing of the Oligocene magmatism of the Bučim-Damjan-Borov Dol ore district: Implications for timing, duration and source of the magmatism.– Lithos, 180/181, 216–233.

SERAFIMOVSKI, T., TASEV, G., STRMIĆ PALINKAŠ, S., PALINKAŠ, L.A. & GJORGJIEV, L. (2016): Porphyry Cu mineralizations related with the small Tertiary volcanic intrusions in the Bučim ore deposit, Eastern Macedonia – Geol. Croat., 69, 101-119.

Estimating Subsurface Lithology Distribution of Pannonian Sediments in Eastern Part of Drava Depression by Geomathematical Methods

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One of the key elements in regional geological subsurface exploration is a valid estimate of lithology distribution. The conventional way is to use different mapping algorithms to determine the properties in the interwell area based solely on well data or using exploration seismics (attribute analysis; RADOVICH & OLIVEROS, 1998) to reduce uncertainty. Lithological properties of rocks in the subsurface are commonly estimated based on well data using either conventional deterministic approach or stochastic algorithms with previously expressed variograms, respecting the already established contacts between the lithostratigraphic units. Since the uncertainty, spatial and temporal variability cannot be avoided, the aim of this research is to estimate the lithological composition of the rocks in the area between wells, as realistically as possible. Variogram, as a starting point, is a basic term of geomathematical analysis which represents random field structure and it can only depend on the distance between the measured points and on the difference in values between them (ANDRIČEVIĆ et al., 2006). In addition to the well data interpretation, an important role in determining the lithological composition has also recently been given to the application of seismic attribute analysis (KOSON et al., 2014, PIGOTT et al., 2013). Artificial neural networks are also used in evaluating the lithological composition (BRCKOVIĆ et al., 2017). In this relatively new method of data processing an algorithm is expected to learn from a set of available data and adapting to new conditions, functioning in the way the biological neural networks do (RUMELHART et al., 1986). The main characteristics of artificial neural networks

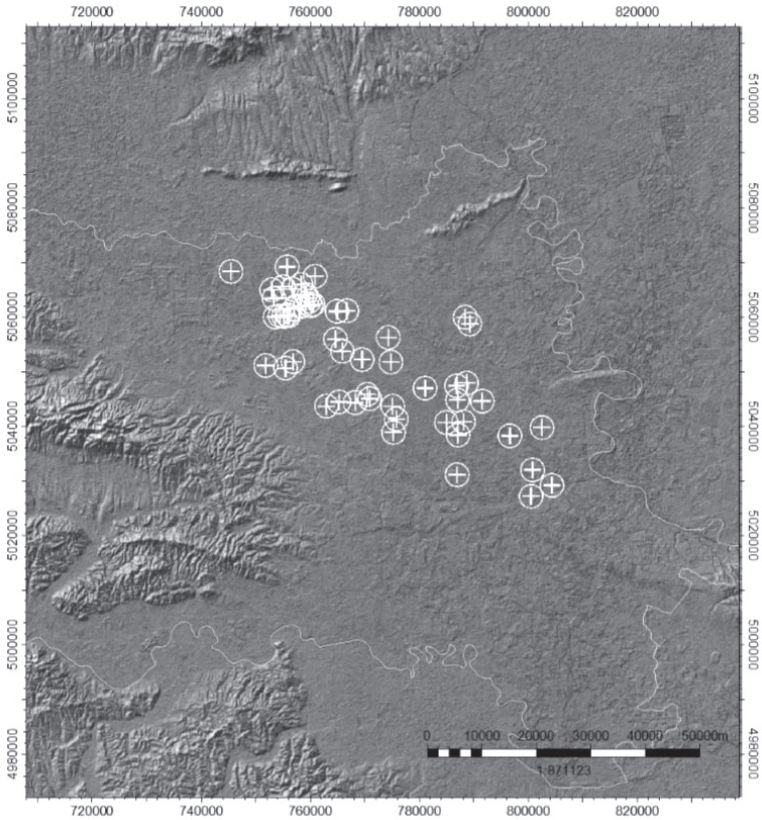

Figure 1. Study area in eastern part of the Drava Depression where well network is located.

are exploiting unclear and incomplete data, good nonlinear evaluation of sample relationships, using a large number of different parameters and acquiring new knowledge through the learning process from previous experiences.

By using the mentioned geomathematical tools, analysis was performed on well data (Fig. 1) from Pannonian sediments in eastern part of Drava Depression. These data includes categorical (lithology categories) and continuous variables (seismic attributes). Since all of this is aimed at better reconstruction of subsurface geology, the main goal of the research is to develop a methodology that will eventually merge well and seismic data with analyses made by artificial neural networks, in order to obtain a more realistic characterization of the lithological composition of clastic sediments in the area between wells, to enable regionally extensive reconstructions.

Keywords: *lithological composition, stochastic approach, variogram, artificial neural networks*

References

ANDRIČEVIĆ, R., GOTOVAC, H. & LJUBENKOV, I. (2006): Geostatistika: umijeće prostorne analize [Geostatistics: the art of spatial analysis – in Croatian]. Faculty of Civil Engineering and Architecture, University of Split, 23.

BRCKOVIĆ, A., KOVAČEVIĆ, M., CVETKOVIĆ, M., KOLENKOVIĆ MOČILAC, I., RUKAVINA, D. & SAFTIĆ, B. (2017): Application of artificial neural networks for lithofacies determination based on limited well data. Central European geology, 60, 3, 299-315.

KOSON, S., PIYAPHONG, C. & CHOOWONG, M. (2014): Seismic Attributes and Their Application in Seismic Geomorphology. Bulletin of Earth Science of Thailand, 6, 1, 1-9.

PIGOTT, J.D., KANG, M.H. & HAN, H.C. (2013): First order seismic attributes for clastic seismic facies interpretation: Examples from the East China Sea. Journal of Asian Earth Sciences, 66, 34-54.

RADOVICH, B.J. & OLIVEROS, R.B. (1998): 3D sequence interpretation of seismic instantaneous attributes from the Gorgon Field. The Leading Edge, 17, 1286-1293.

RUMELHART, D.E., HINTON, G.E. & WILLIAMS, R.J. (1986): Learning internal representations by error propagation. In: RUMELHART, D.E. & MCCLELLAND, J.L. (eds.): Parallel Distributed Processing, MIT Press, Cambridge, 1, 381-362.

The Climate Change in the Seas Around China Since 1870

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The seas out of mainland of China include the East China Sea, the South China Sea and adjacent waters to the Northwest Pacific Ocean (NPO). Using multiple marine data set (AIPOcean1.0 (1993–2006), Ishii (1945–2010), SODA (1871–2010)), temperature analysis indicates temporal changes. The rate and trend from surface to the deep water in the area, from 1871, indicate larger differences in space and time: on the surface, the warming was observed in the whole study area since 1870; the warming rates appear larger over 25 years > 50 years > 100 years > 140 years. But the largest warming was in the layer at approximate depth of 50m. In the continental shelf area of the East China Sea, where the water depth is less than 160 meters, the temperature was rising in the upper layer up to 100 meters, but in some areas cooling appeared deeper than 120 meters.

In the Kuroshio Current in the East China Sea and the Okinawa trough region, from the entrance to exit of the Kuroshio Current in the East China Sea, the sea is warmer in the upper 300 m and the warming rate decreased with depth; the layer between 500–700 meters in some areas appear to be cooling; the layer deeper than 700 meters appears to warm again.

At the NPO adjacent to the East China Sea, the upper 200 meters appear to warm, a cooling trend was found at 300–1200 meters, no change or apparent weak warming was found below 1200 meters. In the South China Sea, the upper 200 meters started to warm, layer between 200–1000 m is cooling, the layer below 1000 meters started to warm again.

In the NPO adjacent to the South China Sea, the upper 250 meters is heating, layer 250–2500 m is cooling, an below 2500 m the change is no obvious. Throughout the study area, in the area deeper than 700 meters, the temperature changes show a three layer structure with the temperature rise in the upper layer, the cooling in the middle layer, whereas in the deeper layer the change is not obvious.

Keywords: *climate change, temperature, East China Sea, South China Sea, Northwest Pacific Ocean*

Transport of Carbonates along the Plitvice Lakes System

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The chain of 16 lakes belongs to the best known Croatian national park – the National Park Plitvice Lakes (NP Plitvice Lakes). During the last 100 years many studies at different level were performed and related papers were published about its climatological, meteorological, hydrological, geological, hydrogeological, geochemical, limnological and biological features. The Plitvice Lakes are monomictic, during the warmer winters, to dimictic, during the strong winters when the surface of lakes are covered with ice. Until today, lakes are mainly oligotrophic with sometimes developed anoxic conditions at the dippiest bottom of the large lakes. Within the scope of project "Hydrodynamic Modeling of Plitvice Lakes System", funded by NP Plitvice Lakes, hydrogeochemical part of study include the geochemical modeling of carbonate transport along the Plitvice lakes water course and simulation of trends connected with natural and human impact. Input data were collected during the period of the last ten years.

Geochemical softwares NETPATH and PHREEQC are used for simulation of climate changes as well as potential anthropogenic impact in future and recognized trends of calcite deposits quantity in lakes and dynamic of tufa barriers growth. Obtained mass transport are compared with results obtained by previous studies which have used different hydrological, geochemical and isotope approach. The most unique and valuable characteristics of lakes system is the formation of tufa barriers that divide the upper part of the Korana River canyon into the two large (Prošćansko jezero and Kozjak) and 14 smaller lakes.

Many authors pointed out that the formation process is very vulnerable on natural and anthropogenic factors. Natural impact is manly consequence of climate changes and manages with few crucial geochemical and hydrological parameters. But the increasing number of visitors are followed with new tourist capacity buildings simultaneously increase the quantity of waste water and organic matter content. Common effect could be tested and obtained trends could be served for design of the future protection measures of the lakes and improve existing management plan.

Keywords: *transport of carbonates, climate changes, anthropogenic impact, Plitvice Lakes*

References

BENCETIĆ KLAIĆ, Z., RUBINIĆ, J. & KAPELJ, S. (2018): Review of research on Plitvice Lakes, Croatia in the fields of meteorology, climatology, hydrology, hydrogeochemistry and physical limnology. Geofizika, Vol. 35, No. 2, 2018, 189-278.

3D Velocity Model of the Crust and Uppermost Mantle in the Area of the Dinarides and Southwestern Pannonian Basin

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The study area represents the boundary zone between the African and European plate i.e., the contact between the Adriatic microplate as part of the African plate and the Pannonian basin as part of the European plate. Recent geophysical efforts greatly contributed to the clarification of the crustal and lithospheric structure in this region. ŠUMANOVAC et al. (2017) imaged a fast velocity anomaly extending underneath the entire Dinaridic mountain belt, whereas KAPURALIĆ et al. (2019) reported first crustal high-resolution 3D velocity model in the northern

Dinarides. This investigation is a continuation of geophysical studies focused on the Dinarides and its adjacent areas. In this study, Local Earthquake Tomography method (LET) was used in order to advance our understanding of the crustal structure and its relationship to the upper mantle in the contact area between the Adriatic microplate and European plate.

P-wave travel-times are calculated from earthquakes, which were recorded by temporary and permanent seismic stations placed in the survey area. Phase arrivals (Pg and Pn phases) were manually picked. The used method employs the multi-stage fast marching method (FMM) as the grid-based forward modelling eikonal solver to predict the travel-times (SETHIAN & POPOVICI, 1999). The non-linear inversion problem is solved by iteratively adjusting model parameters in order to reconcile the objective function (e.g., velocity, interface depth, and/or source location) and travel-time perturbations (i.e., achieved with a subspace inversion scheme; see KENNETT et al., 1988). The study resulted in a new crustal and upper mantle three-dimensional (3D) P-wave velocity model, which provides new insights on the deep geologic features. The inverted velocity model shows that the crust under the Dinarides is characterized by relatively stronger lateral and vertical velocity changes when compared to the crust in the Pannonian basin area. The velocity model reveals crustal thickening beneath the Dinarides and significant crustal thinning beneath the Pannonian basin. The most reliable feature in the model concerns the structure of the Mohorovičić discontinuity. The Moho shape can be determined in vertical cross sections based on the highest vertical velocity gradient in the lower crust. Tomography model indicates that the Moho flanks could be steep and with a sudden increase in depth on both sides of the Dinarides. There is a deep low-velocity zone beneath the Dinarides (Fig. 1), which extends to a depth of more than 50 km and has characteristic NW–SE trending. The pronounced low-velocity anomaly ($V_p \approx 7$ km/s) is surrounded by higher velocity of about 8 km/s that is a typical velocity in the uppermost mantle. This zone could be interpreted as the fragmentation in the uppermost mantle. The low-velocity anomaly in the upper mantle correlates well with the Moho fragmentation determined by the geometrical relationships (Fig. 1). In the map of the Mohorovičić discontinuity obtained by gravity modelling, the fragmentation is interpreted based on the asymmetry of the flanks at the Moho below the Dinarides (ŠUMANOVAC, 2010). High-velocity and low-velocity alteration in the narrow area below the Dinarides could be the first geophysical evidence of the contact of two upper mantles in the survey area. According to the velocity pattern, the contact zone can be located on the NE flank of the Dinarides.

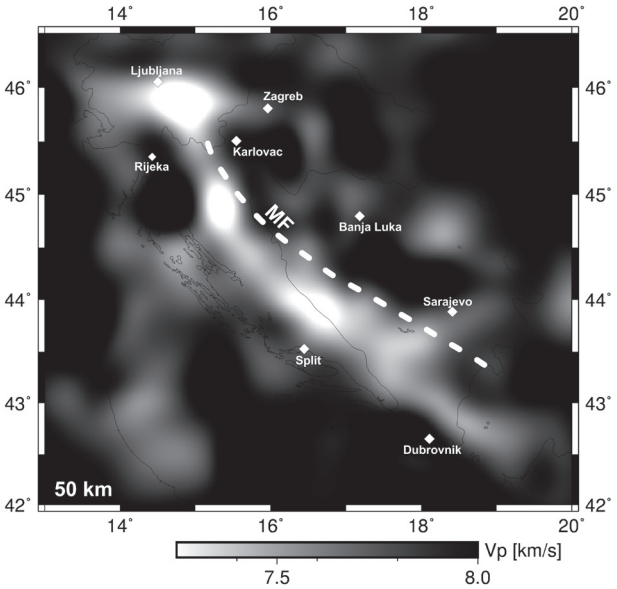

Figure 1. Horizontal slice through the P-wave inversion model showing low-velocity anomaly beneath the Dinarides at a depth of 50 km. MF – Moho fragmentation (after ŠUMANOVAC, 2010).

Keywords: *Dinarides, SW Pannonian Basin, travel-time tomography, 3D velocity model, Upper mantle structure*

References

KAPURALIĆ, J., ŠUMANOVAC, F. & MARKUŠIĆ, S. (2019): Crustal structure of the northern Dinarides and southwestern part of the Pannonian basin inferred from local earthquake tomography. Swiss Journal of Geosciences, 112, 181-198.

KENNETT, B.L.N., SAMBRIDGE, M.S. & WILLIAMSON, P.R. (1988): Subspace methods for large scale inverse problems involving multiple parameter classes. Geophysical Journal, 94, 237-247.

SETHIAN, J.A. & POPOVICI, A.M. (1999): 3-D traveltime computation using the fast marching method. Geophysics, 64, 516-523.

ŠUMANOVAC, F. (2010): Lithosphere structure at the contact of the Adriatic microplate and the Pannonian segment based on the gravity modelling. Tectonophysics, 485, 94-106.

ŠUMANOVAC, F., MARKUŠIĆ, S., ENGELSFELD, T., JURKOVIĆ, K. & OREŠKOVIĆ, J. (2017): Shallow and deep lithosphere slabs beneath the Dinarides from teleseismic tomography as the result of the Adriatic lithosphere downwelling. Tectonophysics, 712-713, 523-541.

Developing a Conceptual Model for Groundwater Flow and Transport Model of Nitrate in the Varaždin Alluvial Aquifer

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Groundwater contamination with nitrate is a major concern in the Varaždin alluvial aquifer. Increased concentrations of nitrate in groundwater are predominantly caused by intensive agricultural activities where synthetic nitrogen fertilizers and manure are being used.

For better understanding of distribution and fate of nitrate, it is necessary to develop a conceptual model of the Varaždin aquifer, which will be used as a foundation for setting up a numerical model of groundwater flow and transport model of nitrate. A conceptual model is a simplified representation of the site to be modelled and requires identification of three key elements: model domain and aquifer geometry, aquifer parameters and boundary conditions.

The research area (model domain) is located upstream of the town of Varaždin and includes the catchment area of the pumping sites "Varaždin" and "Vinokovščak". The aquifer of the research area is unconfined and represented by Pleistocene and Holocene alluvial deposits, which are primarily composed of gravel and sand with variable portions of silt. Groundwater generally flows from northwest to the southeast, parallel to the Drava River. The covering layer of the aquifer is not continuously developed and there is a high risk of contamination from the surface. The aquifer is recharged by precipitation infiltration through unsaturated zone and by surface water percolation. Aquifer geometry will be determined from geological maps, existing boreholes, geophysics data and geological cross sections. Aquifer parameters will be obtained from available results of field measurements and parameters for which is lack of field data will be estimated from the literature. Determination of appropriate boundary conditions will be based on analysis of head contour maps for high, medium and low groundwater levels.

For the research purposes, a monitoring network of ten observation wells and four surface water locations has been established. Water sampling is conducted on a monthly basis for chemical analyses. Results of chemical analyses can identify the zones with elevated nitrate content in groundwater and combined with land use analysis, can help to locate the surface sources of nitrate for the model.

Acknowledgements

The research is performed as part of the TRANITAL project that is funded by the Croatian Science Foundation (HRZZ) and supported by Young Researchers Career Development Project – Training of New PhDs – HRZZ & ESF.

Keywords: *nitrate, groundwater modelling, Varaždin aquifer*

Influence of a Zagreb Central Wastewater Treatment Plant on a Geochemical Characteristic of Sava River Sediment

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Field sampling of water and sediments from Sava river in Zagreb, in a total length of 36,73 km was collected in March 2019, with the goal to determine the geochemical characteristic of sediment in the vicinity of discharge at main outlet of a Zagreb central wastewater treatment plant. Samples were collected under the Jankomir bridge (a), Bridge of Youth (b), a zone of outlet (c) and in Rugvica (d) (Fig. 1). In all water sample pH and electrical conductivity (EC) were measured. Results are similar for 3 of 4 locations (pH around 8, and EC around 430 μs). The sample from

Figure 1. Sampling locations (Sorce: Google Maps, 28.05.2019.)

location c shows an increase in electrical conductivity (844 μs) and decrease of pH value (7,65). All sediment samples were dry to constant weight and divided into the two sub-samples. The first one was used for bulk analysis, while the second one was sieved and fraction < 0,063 mm was collected for further analysis. The qualitative mineral phase composition was performed, to determine the mineral phases by the Philips X'pert powder diffractometer with CuKα radiation from the tube operating at 40 kV and 45 mA. An X-ray diffraction data set was collected from 4° to 63° 2Θ.

All analysed bulk samples have a similar composition, with the quartz as the main phase, calcite, dolomite, muscovite and kaolinite as phases presented in smaller amount. In the fraction < 0,063 mm quartz was also determined as main mineral phase and all phases from bulk are present with adition phases, albite and magnesium calcite. The amount of carbonate component was also determined by the Austrian standard methods ÖNORM L1084 using Scheibler calcimeter. Amount of carbonate component decrease downstream, but all bulk samples have a high amount of a $CaCO_3$ components, from 36% to 29,5%. Qualitative and quantitative chemical analysis of metals in sediment and water as well as sequential extraction chemical analysis by BCR protocol was performed and results will be presented at the poster, due to the additional data processing which must be performed.

Keywords: *Sava river sediment, wastewater treatment plant, BCR analysis, Geochemical analysis*

References

ÖNORM, L., 1084 (1999): Chemische Bodenuntersuchungen– Bestimmung von Carbonat. Wien

OREŠČANIN, V., LULIĆ, S., PAVLOVIĆ, G. & MIKELIĆ, L. (2004): Granulometric and chemical composition of the Sava River sediments upstream and downstream of the Krsko nuclear power plant. Environmental Geology, 46, 605-613.

PAVLOVIĆ, G., PROHIĆ, E., & TIBLJAŠ, D. (2004): Statistical assessment of geochemical pattern in overbank sediments of the river Sava, Croatia. Environmental Geology, 46, 132-143.

PAVLOVIĆ, P., MARKOVIĆ, M., KOSTIĆ, O., SAKAN, S., ĐORĐEVIĆ, D., PEROVIĆ, V., PAVLOVIĆ, D., PAVLOVIĆ, M., ČAKMAK, D., JARIĆ, S., PAUNOVIĆ, M. & MITROVIĆ, M. (2019): Evaluation of potentially toxic element contamination in the riparian zone of the River Sava. Catena, 174, 399-412.

RAURET, G.F., LOPEZ-SANCHEZ, J., SAHUQUILLO, A., RUBIO, R., DAVIDSON, C., URE, A. & QUEVAUVILLER, P. (1999): Improvement of the BCR three step sequential extraction procedure prior to the certification of new sediment and soil reference materials. Journal of Environmental Monitoring, 1, 57-61.

Late Holocene Storm Deposit and Boulders on the Island of Mana (NP Kornati, Central Adriatic, Croatia)

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Recent studies of the rocky shore in southern Istria resulted in the first published scientific paper about the coastal boulders in the Eastern Adriatic (BIOLCHI et al., 2019). Following this experience, during geological mapping and research for new Basic geological map of the National Park Kornati in scale 1:50,000 (BRČIĆ et al., 2019), the spatially largest unified Adriatic storm deposit, which includes limestone boulders, is discovered on the island of Mana (Fig. 1).

The island is located in the central southern part of the Kornati archipelago, built of deformed Upper Cretaceous shallow-water carbonates that belong to the External Dinarides (KORBAR, 2009; KORBAR et al., 2010). The carbonates are deeply karstified during Quaternary, while steep southern coast point to recent erosion and collapses along the tectonically predisposed unstable cliffs. In the western part of the island, there is an elongated valley of Dinaridic strike (NW-SE), which is on the western and eastern sides covered by a shallow sea. Limestone bedrock along the valley is unconformably covered by erosional remnants of Quaternary brown soil characterized in places by the reddish-brown calcrete at the base, while in the eastern part the bedrock is covered by a unique storm deposit. The stratigraphic relation of the three geological units is clear because the storm deposit unconformably overlay both, the bedrock carbonates and the brown soil. The storm deposit is located 20-30 m NW of a small shallow triangular inlet, located at the central part of the southern coastal cliff submerged partly during Holocene sea level rise. The inlet is formed during the latest sea-level rise at the hypsometrically lowest top of the cliff. Accordingly, it can be concluded that the storm deposit is formed during the late Holocene. The cliff rises from the sea up to 50 m west and east of the inlet, and to the south plunges into the sea almost vertically to a depth of almost 90 m https://geoportal.dgu.hr/).

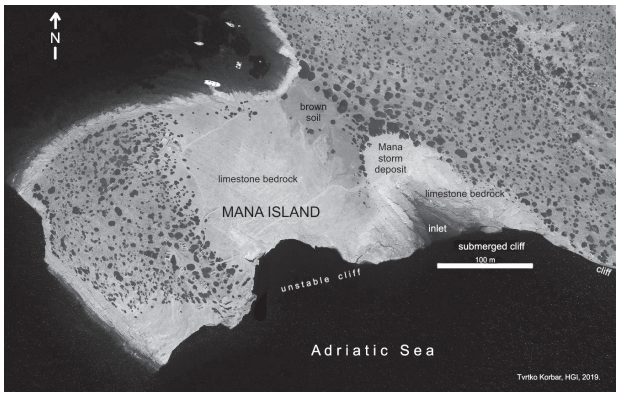

Figure 1. Orthophoto image of the SW part of the island of Mana (https://geoportal.dgu.hr/) and the interpretation showing late Holocene Mana storm deposit that unconformably overlay Upper Cretaceous limestone bedrock and Quaternary brown soil (NP Kornati, Central Adriatic, Croatia).

The Upper Cretaceous bedrock surrounding the inlet is built of alternating thin to thick bedded mostly micritic limestones, which are inclined to the south-west. Subvertical fractures within the limestones are arranged decimeters to meters apart, which together with the bedding discontinuities define fragments of carbonate layers. The storm deposit has an irregular semi-circular shape (80x60 m) which covers an area of ~3500 m^2, wherein the central part is of the estimated thickness of >2 m. The deposit is composed of unsorted pebbles, cobbles, and boulders, on which, in some places, there are still attached erosional remnants of the reddish-brown calcrete. In the frontal SE part of the storm deposit there are meter-sized boulders that are clearly imbricated to the SE. At the edges of the valley, there are solitary boulders, some of which are located up to ~15 meters above sea level and some have traces of boring marine organisms, which prove the submarine origin of the boulders.

Preliminary storm waves modelling indicates that this part of the central Adriatic is exposed to the extreme southern to southeastern waves formed by strong Sirocco wind, which are necessary for the erosion of the rocky coast and displacement of the meter-sized limestone boulders up to 100 m from the coastline. Slightly concave southern cliff of the island of Mana and the shallow inlet in the central part of the cliff, probably can additionally channelize the storm waves, that could detach the boulders from fragmented carbonate bedrock at the bottom of the shallow inlet and surroundings, and displace the boulders inland.

Accurate measurements of the boulders and wave modelling will enable more precise calculations of the height of the extreme waves that hit this geographically, geologically and geomorphologically predisposed microlocality characterized by the spatially largest known unified storm

deposit on the Adriatic coast. The age of subrecent marine biological encrustations that are recognized on some storm boulders could allow approximal correlation of the periods of extreme storms that thrown the boulders out of the sea at this and other sites. In turn, this could allow the correlation between the extreme storm periods and the recorded climate change during the late Holocene in this part of the Mediterranean, and perhaps could allow the prediction of future extreme weather events.

Keywords: *rocky shore, Holocene, extreme waves, coarse-clastic sediment, coastal boulders.*

References

BIOLCHI, S., FURLANI, S., DEVOTO, S., SCICCHITANO, G., KORBAR, T., VILIBIĆ, I. & ŠEPIĆ, J. (2019): The origin and dynamics of coastal boulders in a semi-enclosed shallow basin: A northern Adriatic case study. Marine Geology, v. 411, 62-77.

BRČIĆ, V., KORBAR, T., FUČEK, L., PALENIK, D., BELIĆ, N., MIŠUR, I. & WACHA, L. (2019): Osnovna geološka karta Republike Hrvatske mjerila 1:50 000 – NP KORNATI: Hrvatski geološki institut, Zavod za geologiju, ISBN: 978-953-6907-72-4, Zagreb.

KORBAR, T. (2009): Orogenic evolution of the External Dinarides in the NE Adriatic region: a model constrained by tectonostratigraphy of Upper Cretaceous to Paleogene carbonates. Earth Science Reviews, 96/4, 296-312.

KORBAR, T., SURIĆ, M., FUČEK, L., MIHELČIĆ, V., VESELI, V. & DROBNE, K. (2010): Geologija kornatskog otočja (Geology of Kornati archipelago). In: HORVAT, M. (ed.), Vodič ekskurzija (Excursion Guide-book), 4. Hrvatski geološki kongres (4th Croatian Geological Congress), Hrvatski geološki institut (Croatian Geological Survey), Excursion B1, 130-142, Zagreb.

Detachment and Parasitic Folds on the Island of Kornat (Central Adriatic, Croatia)

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During the detailed geological mapping for the purposes of a new Basic geological map of National Park Kornati in scale 1:50,000 (BRČIĆ et al., 2019), so far unknown tectonic deformations of the Adriatic carbonate platform succession are observed. The western part of the island of Kornat is built almost entirely of >600 m thick succession of well-bedded, lithologically monotonous, mostly micritic peritidal limestones. The competent carbonate rock succession is intensively folded in form of kilometers long folds characterized by the typical Dinaridic strike (NW-SE), and a clear SW vergence (Fig. 1A). These folds are symmetrical, asymmetrical, and overturned, up to a kilometer high (anticlines and synclines) and thus are considered as the first-order folds characterized by a different amount of compaction during orogenic shortening. These huge folds are associated with decametric second-order asymmetric parasitic folds intercalated within the successions of the Gornji Humac formation, in moderately inclined limbs of the first-order folds. The zones of parasitic folding strike continuously along many kilometers, and the estimated thickness between concordant underlying and overlying limestone succession is 100–200 m. The parasitic folds have typical „Z" and „S" geometry (Fig. 1B), although in places deformations seem rather chaotic (without any uniform vergence). The parasitic folds are in places dissected by indistinct internal faults. It should be noted that parasitic folds are not observed in the subvertical and overturned limbs of the first-order tight folds.

The genesis of the first-order folds on the island of Kornat is probably related to a detachment (décollement) folding as described e.g. in DAVIS & REYNOLDS (1996). The lack of the parasitic folding within the steep (and overturned) limbs of the tight first-order folds can be explained by the simultaneous formation of the both, the tight and open first-order folds. Parasitic folds (the second-order folds) are likely formed simultaneously with the formation of the first-order open folds (anticlines), because of a lateral thickness compensation within the folded thrust sheet during the tectonic thickening, since the tight folds are generally higher than open folds.

According to the exclusive surface appearance of the Upper Cretaceous and Paleogene deposits in the wider region, we assume that detachment has been activated within older Mesozoic deposits during the early-orogenic thin-skinned tectonic phase in the area (KORBAR, 2009). However, considering a few kilometers thick deformed Upper Cretaceous carbonates in the boreholes on the neighbouring island of Dugi otok (cf. FUČEK et al., 2016), the tectonic structure in this part of the External Dinarides was probably formed as a multiple thrust structure. The frontal

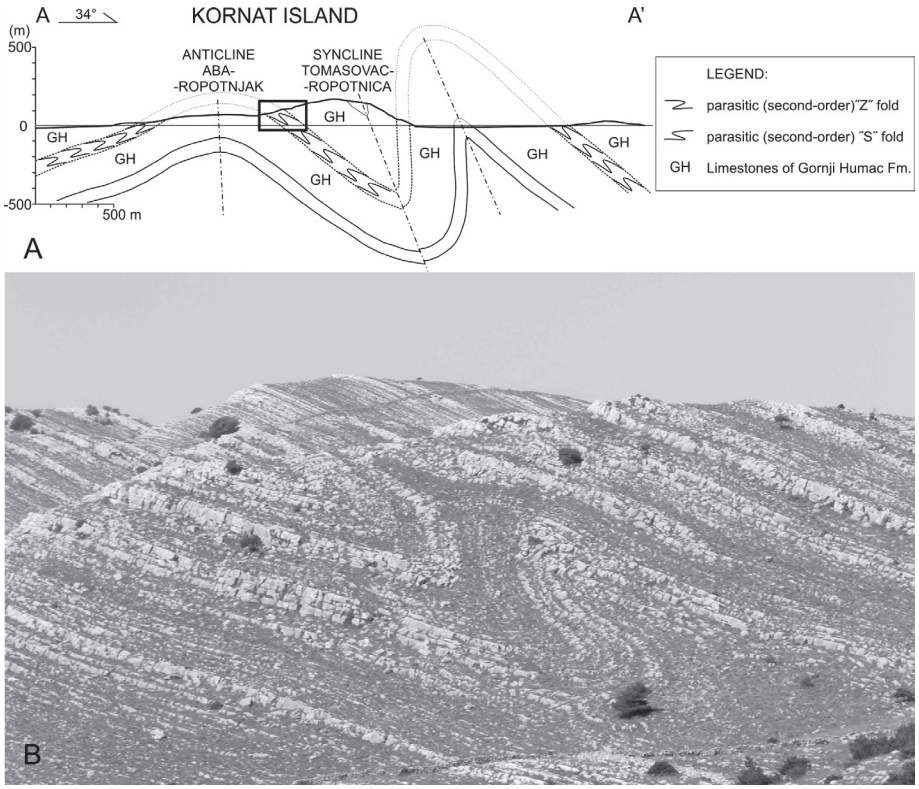

Figure 1. A) Transversal geological cross-section A-A' of the western part of the island of Kornat, showing the relation of the first-order and the second-order (parasitic) folds, and B) Panoramic photograph of a typical „S" parasitic fold in the NE limb of the first-order open anticline Aba-Ropotnjak (NW part of the island of Kornat). Approximate position of the photograph is marked by thick rectangle on the cross-section (photo: T. Korbar, 2018).

thrust of the External Dinarides, previously interpreted on the seismic profiles (GRANDIĆ et al., 2002; KORBAR et al., 2010), is located beneath the seabed about 20 kilometers southward of the island of Kornat, and is probably related to the latest activity of once active main décollement (detachment) at the base of the External Dinarides. According to our knowledge, this is the first report on parasitic folding in the External Dinarides.

Keywords: *External Dinarides, shallow-water carbonates, décollement folding, parasitic folds*

References

BRČIĆ, V., KORBAR, T., FUČEK, L., PALENIK, D., BELIĆ, N., MIŠUR, I. & WACHA, L. (2019): Osnovna geološka karta Republike Hrvatske mjerila 1:50 000 (*Basic Geological Map of the Republic of the Croatia, scale 1:50,000*) – NP KORNATI: Hrvatski geološki institut (*Croatian Geological Survey*), Zavod za geologiju (*Department of Geology*), ISBN: 978-953-6907-72-4, Zagreb.

DAVIS, G.H. & REYNOLDS, S.J. (1996): Structural geology of rocks and regions. John Wiley & Sons, Inc. 776 p., New York.

FUČEK, L., JELASKA, V., PRTOLJAN, B., KOROLIJA, B., OŠTRIĆ, N. & GUŠIĆ, I. (2016): Osnovna geološka karta Republike Hrvatske mjerila 1:50 000 (Basic Geological Map of the Republic of the Croatia, scale 1:50,000) – Dugi otok: Hrvatski geološki institut (*Croatian Geological Survey*), Zavod za geologiju (*Department of Geology*), ISBN: 978-953-6907-58-8, Zagreb.

GRANDIĆ, S., VESELI, V. & KOLBAH, S. (2002): Hydrocarbon potential of Dugi otok basin in offshore Croatia. Nafta, 53/6-7, 215–224.

KORBAR, T. (2009): Orogenic evolution of the External Dinarides in the NE Adriatic region: a model constrained by tectonostratigraphy of Upper Cretaceous to Paleogene carbonates. Earth Science Reviews, 96/4, 296–312.

KORBAR, T., SURIĆ, M., FUČEK, L., MIHELČIĆ, V., VESELI, V. & DROBNE, K. (2010): Excursion B1: Geologija kornatskog otočja (*Geology of Kornati archipelago*). In: HORVAT, M. (ed.): Vodič ekskurzija (*Excursion Guide-book*), 4. Hrvatski geološki kongres (*4th Croatian Geological Congress*), Hrvatski geološki institut (*Croatian Geological Survey*), 130-142, Zagreb.

Application of Geodetic Techniques in Geological Studies of the Plitvice Lakes National Park

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Plitvice Lakes, a unique hydrocarstic phenomenon situated in the External Dinaridic region, is the oldest and largest national park in Croatia. Understanding the evolution and formation of the lakes through the Quaternary and the fragile natural balance that sustains them inevitably requires consideration of their inherited geological framework that underlies the lakes. In 2017, a three-year project funded by the Plitvice Lakes National Park was initiated in order to improve existing knowledge on the tectono-stratigraphic evolution, paleogeography and Quaternary evolution of the Plitvice lakes area through the application of carbonate sedimentology, micropaleontology, structural geology and state-of-the-art geodetic techniques. UAS photogrammetry and interferometric multibeam sonar system are used to build models of individual geological outcrops and bathymetric maps of lakes (Fig. 1) with a high level of resolution and spatial accuracy. These first time applied geodetic techniques and tools in the Plitvice Lakes National Park offer exceptional visualization opportunities for Park visitors to comprehend the geological framework of the lake system and its evolution through the Quaternary. Moreover, applied geodetic techniques provide an essential analytical dataset for understanding and improving existing geological models that may help in the protection of this fragile hydrocarstic system exposed to enormous anthropogenic pressure. Beside excellent educational and science popularization tool, recorded digital outcrop and bathymetry map of the lakes are effective methods of documenting and surveying important geological locations potentially endangered by human activity.

In this study three Triassic and Cretaceous carbonate outcrops, together with Lakes Kozjak and Prošćansko bathymetry were digitally captured within the Plitvice Lakes National Park using UAS photogrammetry and multibeam sonar, respectively. The outcrops were recorded using a custom made unmanned multi-rotor system and Sony Alpha 7R digital camera with 36.3-megapixel full-frame sensor and Sony FE 35mm Carl Zeiss lens. High precision positioning of camera shots was achieved using multi-frequency Septentrio AsteRx-m GNSS receiver. Over 1000 oblique photographs were used together with positioning data to construct 3D scenes (Fig. 1) employing Structure from Motion algorithms. Hydrographic surveying of Lakes Kozjak and Prošćansko bottom surface was performed using Bathyswath-2-UW interferometric multibeam echosoun- der (PUJOL et al., 2012),

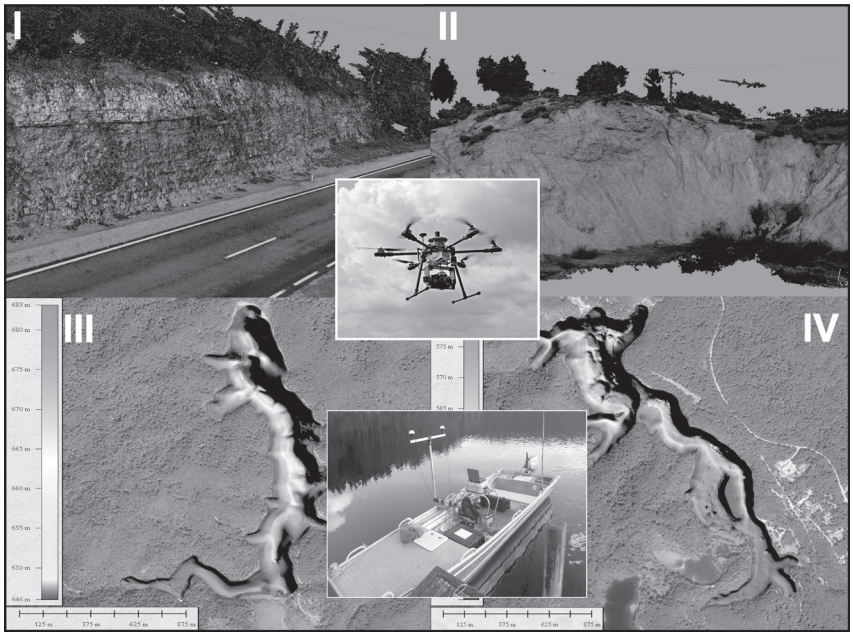

Figure 1. 3D virtual outcrop modes of (I) an Upper Cretaceous limestone sequence and (II) Upper Triassic dolomites in the in the vicinity of Prijeboj. Results of hydrografic surveying of Lake Kozjak (III) and Lake Prošćansko (IV).

whereas positioning and orientation was achieved using SBG-Systems Ekinox-A motion reference units (MRU) that gives attitude information for roll, pitch and heave parameters. Precise position and heading information was obtained using Hemisphere Vector VS330 dual antenna with Eclipse GNSS technology. The results are detailed high-resolution 2D and 3D outcrop and lake-bottom models (Fig. 1) with centimeter level accuracy in the form of colored-code point clouds or mesh surfaces.

Besides effective visualization, constructed outcrop and lake-bottom models can be analyzed structurally, stratigraphically and hydrographically (e.g. PRINGLE et al., 2010). This may imply interpretation and modeling of specific lithostratigraphic facies and discontinuities, as well as accurate measurement of identified structural features, *i.e.*, bedding, fault and fracture plane systems. The digital models are particularly useful for spatial reconstruction of dislocated features, *i.e.*, strata beds, fault planes, tectonostratigraphic facies that are in most cases visible only on individual parts of large segmented outcrops. Modeled surfaces and facies can be further used for volume calculations and 3D modeling. Bathymetry data can also be used for temporal monitoring of lakes bottom changes.

Keywords: *NP Plitvice Lakes, UAV photogrammetry, interferometric multibeam sonar system, 3D geological modelling, hydrographic surveying*

References

PUJOL, G.L., SINTES, C., CHONAVEL, T., MORRISON, A.T. & DANIEL, S. (2012): Advanced interferometric techniques for high resolution bathymetry. J. Mar. Tech. Soc., 46, 9-31.

PRINGLE, J.K., BRUNT, R.L., HODGSON, D.M. & FLINT, S.S. (2010): Capturing stratigraphic and sedimentological complexity from submarine channel complex outcrops to digital 3D models, Karoo Basin, South Africa. Petrol. Geosci., 16, 307-330.

Method for Measurment and Determination of Density and Intensity of Fractures in Layered Rock of Kornati Islands

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Characterizations of fractures have an important role in describing the rock masses. Some geometrical characteristics of fractures which are evaluated in this research are intensity and density (measures of abundance). These characteristics / measures are important and commonly used for characterizations of fractures in rock masses (BANDPEY et al., 2019).

Furthermore, according to KAMALI et al. (2016) these characteristics are beneficial and important for estimating the elastic properties of the rock masses, porosity of fractures, rock mass description for determining its hydraulic and mechanical behavior, prediction of In-situ Blok Size Distribution (IBSD), etc. Determination of the fracture abundance is also necessary for Discrete Fracture Network (DFN) modelling and verification (KAMALI et al., 2016).

In this research the above characteristics are estimated using three methods: scanline sampling, window sampling, and circular sampling methods.

Sampling methods, such as scanline sampling (linear sampling methods), window sampling, and circular sampling (areal sampling methods) are used to estimate the correlation of fracture geometrical characteristics with their position in larger geological structures. To provide a high availability of data required for density and intensity measurements in the layered carbonate rocks, three conditions are required: (1) areas of slightly deformed geological structures; (2) well defined lithology, and (3) surface area not covered by vegetation.

According to the mentioned conditions, the area of Kornati islands was found as suitable area for investigation and three locations were selected for detailed research there. Kornati islands region (northern Dalmatia, Croatia) are predominantly built from Upper Cretaceous to Eocene pre-orogenic layered carbonates rocks (KORBAR et al., 2010) with well-defined regional and local geological structural settings. Surface of the terrain on all three locations (Magazinova Škrila, Tureta and south part of island Levernaka) is formed by layers of very high persistence, without vegetation, with very pronounced natural cuts providing high availability of fracture traces on which measurements of density and intensity analysis were performed. Magazinova Škrila and Tureta are built of middle to thick layered rock, belonging to Gornji Humac Formation (GHN; K_2^{2-5}), and south part of island Levernaka belongs to unit with thin layered carbonates rock named Milna Formation (MF; K_2^{1}) (BRČIĆ et al., 2019).

The preliminary field research included: geological and engineering geological mapping, standard measurement methods, and digital photogrammetry methods which are divided into (1) terrestrial photogrammetry – ShapeMetrix3D (ShapeMetriX3D; 3G Software & Measurement GmbH, 2007) and (2) aerial photogrammetry – Unmanned Aerial System.

Fracture abundance is defined in 1, 2 and 3-dimensions. It is difficult to directly measure all the fractures and their properties in 3-D space (ZHENG et al., 2017). Therefore, it is widely accepted to infer fracture properties from one-dimensional (linear sampling methods) and two-dimensional (areal sampling methods) measurements in order to estimate three-dimensional properties of rock mass (Fig. 1) (ZHANG, 2017).

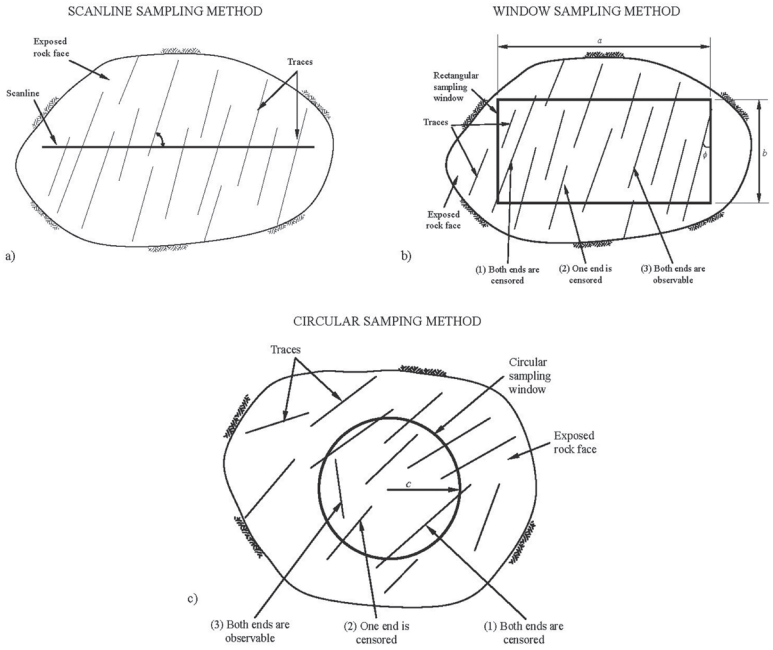

Figure 1. Schematic illustration of: a) scanline, b) window and c) circular sampling methods (ZHENG, 2017).

Linear (scanline sampling) and areal (window and circular sampling) methods vary in their application, and the parameters they provide have advantages and limitations (ZEEB et al., 2013). Orientation, truncation, censoring, and size bias, among others, can cause significant errors in statistical parameters estimation and thus can potentially affect the characterization of fracture networks (ZHANG & EINSTEIN, 1998). The scanline and window sampling method is affected by orientation, truncation and censoring bias, except size bias, which affects only the scanline sampling method. The circular sampling method is not subject to sampling bias. This method does not provide information on important parameters such as fracture orientation, length distribution, or width. If possible, all three methods should be combined.

Geostatistical analyses will quantify the spatial continuity of fractures and will define spatial distributions of fracture density and intensity in layered carbonate rocks. Along with geostatistical analyses, directional statistics (circular and spherical statistical analyses) will be carried out with aim to quantify all the geometrical features of the fracture.

Lithology and thickness of the layers will be correlated with the intensity and density of the fractures in layered carbonate rocks.

This research will also examine the hypothesis that thickness of layers, their physical – mechanical properties and their position in larger geological structures have influence on the density and intensity of the fractures in layered carbonate rocks.

Keywords: fracture, linear and areal sampling, geometrical characteristics, statistical analysis

References

BANDPEY, A.K., MAREFVAND, P., SHAHRIAR, K. & SHARIFZADEH, M. (2019): Comparison of methods for calculating geometrical characteristics of discontinuities in a cavern of the Rudbar Lorestan power plant: Bull Eng Geol Environ, v. 78, 2, 1073-1093.

BRČIĆ, V., KORBAR, T., FUČEK, L., PALENIK, D., BELIĆ, N., MIŠUR, I. & WACHA, L. (2019): Osnovna geološka karta Republike Hrvatske mjerila 1:50 000 – NP KORNATI: Hrvatski geološki institut, Zavod za geologiju, ISBN: 978-953-6907-72-4, Zagreb.

KAMALI, A., SHAHRIAR, K., SHARIFZADEH, M., AALIANVARI, A. & ESMAEILZADEH, A. (2016): Effect of shape and size of sampling window on the determination of average length, intensity and density of traces discontinuity. ISRM International Symposium – EUROCK 2016, 29-31 August, Ürgüp, Turkey.

KORBAR, T., SURIĆ, M., FUČEK, l., MIHELČIĆ, V., VESELI, V. & DROBNE, K. (2010): Geology of Kornati archipelago. Excursion Guide-book. 4th Croatian Geological Congress – Šibenik.

ZHANG, L. & EINSTEIN, H.H. (1998): Estimating the mean trace length of rock discontinuities: Rock Mechanics and Rock Engineering, v. 31, no. 4, 217-235.

ZHANG, L. (2017): Engineering Properties of Rocks. University of Arizona Tucson, Arizona, United States, 90-116.

ZHENG, J., ZHAO, Y., LÜ, Q., LIU, T., DENG, J. & CHEN, R. (2017): Estimation of three-dimensional density of discontinuity system based on one-dimensional measurements. International Journal of Rock Mechanics & Mining Sciences, 94, 1-9.

ZEEB, C., GOMEZ-RIVAS, E., BONS, P.D. & BLUM, P. (2013): Evaluation of sampling methods for fracture network characterization using outcrops. AAPG Bulletin 97, 9, 1545-1566.

3G SOFTWARE & MEASUREMENT GMBH (2007): ShapeMetriX 3D – 3D imaging for measuring and assessing rock and terrain surface. User Manual for Version 2, Graz.

Synthetic Zeolites and Plants as a Remediation Strategy in Case of a Coal-Polluted Ecosystem (Raša, Istria, Croatia)

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Increasing trends of industries, urban cities, and agricultural activities contribute to widespread problems of environmental pollution. Not all pollutants are safely processed and stored, but a certain portion gets emitted into the air, water, soil, and finally in food-chain. Since many organisms have a low ability to cope with environmental degradation, it can result in numerous health problems. In order to decrease environmental pollution, or even restrain it, new ways of environmental recovery are introduced. One of them is phytoremediation, based on the accumulation and tolerance of heavy metals and other substances in plants. They can exhibit rapid growth rate while tolerating high concentrations of heavy metals in harvestable tissues. Plants with these characteristics can be used both for soil and water remediation, depending, of course, on type of pollution, soil type, purpose, affected area, etc. Furthermore, it is well known that specific minerals also have the ability to remediate soil and water. These minerals are zeolites, hydrated alumosilicate minerals made from interlinked tetrahedral silica and alumina in the process of alteration and diagenesis of volcanic ash. Zeolites form with many different crystalline structures, both natural and synthetic, but what they all have in common are open pores or channels. Positively charged ions are present in those channels, and they can easily be exchanged with other ions through selective and reversible ion exchange, the process characteristically used in the removal of heavy metals and radioactive substances from air, soil, and water. They have a large affinity for heavy metals such as nickel, zinc, chromium, and lead (WHITEHEAD, 2000).

Taking into account their characteristics, zeolites have a big influence on everyday's life. They are used in medicine, in chemical processes, filters, etc., and also have a big importance in wastewater treatment due to their affinity for chromium, arsenic, and silver. Because of the growing applications, many of today's known zeolites are modified or synthesized to improve their natural characteristics. Thus, for example, conversion of natural zeolite to Na-form increases its affinity for chromium ions. Fe-modified zeolites show up to the 4-fold increase in the zinc- and cadmium-binding capacity, compared to natural ones, without any change in the structure or mineral composition.

Table 1. Metal levels (μg/L) in original (1-5), zeolite treated (1Z-5Z), and activated zeolite treated (1A-5A) surface stream water (non-filtered) samples collected from the Krapan stream (Krapan town, Raša county, Istria, Croatia).

Sample No.	Fe	Ni	Sr	Ba
1	10.6	1.40	908	27.6
1Z	15.9	1.43	27.0	1.57
1A	46.0	0.78	0.24	0.39
2	25.8	0.98	721	26.1
2Z	19.6	0.89	3.00	0.33
2A	5.00	0.41	0.54	0.21
3	12.0	1.00	732	25.7
3Z	168	1.24	1.21	0.95
3A	29.1	0.65	1.29	0.29
4	81.3	1.69	798	33.6
4Z	33.6	2.63	3.84	0.55
4A	20.7	1.60	2.94	0.50
5	26.6	1.22	786	33.7
5Z	34.0	2.63	9.34	1.02
5A	32.2	1.29	18.6	1.65

On the east coast of Istria (Labin city area), environment has been polluted with superhigh-organic-sulphur Raša coal and ash particles (MEDUNIĆ et al., 2016, 2018). Local soil and surface water are polluted with a range of potentially toxic trace elements (Se, Cd, Zn, Cu, Pb, V, U, Mo, etc.), and they require some sort of remediation. Based on previous research on the remediating effects of zeolites on the environment, i.e. their high affinity towards heavy metals, the aim of this study was to determine the efficiency of synthetic zeolites, along the phytoremediation strategy, in terms of remediation of Raša coal-mine water. For this purpose, synthetic zeolites, produced in Zeochem Ltd. (Zvornik), and Alumina Ltd. (Zvornik),were applied on several (n=5) surface water samples collected from the Krapan stream (Raša town county).

Keywords: coal-mine water, metal pollution, remediation, zeolite, plants

References

MEDUNIĆ, G., RAĐENOVIĆ, A., BAJRAMOVIĆ, M., ŠVEC, M. & TOMAC, M. (2016): Once grand, now forgotten: what do we know about the superhigh-organic sulphur Raša coal? The Mining-Geology-Petroleum Engineering Bulletin, 27-45.

MEDUNIĆ, G., KUHARIĆ, Ž., KRIVOHLAVEK, A., ĐUROKOVIĆ, M., DROPUČIĆ, K., RAĐENOVIĆ, A., LUŽAR OBERITER, B., KRIZMANIĆ, A. & BAJRAMOVIĆ, M. (2018): Selenium, Sulphur, Trace Metal, and BTEX Levels in Soil, Water, and Lettuce from the Croatian Raša Bay Contaminated by Superhigh-Organic-Sulphur Coal, Geosciences 2018, 8, 408, 18 p.

WHITEHEAD, K. (2000): The Application of Synthetic Zeolites for the Removal of Heavy Metals from Contaminated Effluents, Unpbl. Doctoral Thesis, University of Surrey, Department of Civil Engineering, 273 p.

Reactivated Channels on Skradinski Buk Tufa Barrier – An Example of Interdisciplinary Approach for Sustainable Management

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Tufa barriers are a unique hydrological and geological phenomenon. They provide specific and diverse hydromorphological conditions thus creating heterogeneous habitats for periphyton. The growth and development of tufa barriers is very sensitive to changes in physico-chemical or biological factors that play a role in the tufa building process. Uncontrolled growth of vegetation can result with barriers drying out, and consequently cessation of tufa formation. The latter was the case in the Krka National Park, Croatia. Despite numerous actions ensured by the National Park protection category, uncontrollable growth of an invasive plant species *Ailanthus altissima* (Mill.) SWINGE resulted with dried water channels along the final and longest tufa barrier – Skradinski Buk. Removal of *A. altissima* reactivated five channels that had been dried for decades. The aim of the research was to develop a multi-criteria model for sustainable management of the Skradinski Buk barrier after the invasive species removal. Periphyton and tufa samples were collected monthly in the period from October 2017 to December 2018 along the established experimental reach comprising of seven sites. In the frame of multidisciplinary research, physico-chemical, biological and geological parameters were measured. Reactivated channels displayed higher nitrites concentration, lower pH and dissolved oxygen concentration probably caused by higher organic matter content originating from forest soil developed on tufa barrier during dry phase. Periphyton community showed more diversity in reactivated streams in comparison to control, presumably due to lower competition and predatory rates and/or intensive organic matter decomposition processes.

Here we put focus on results of granulometric and mineralogical analysis. In order to determine granulometric characteristics of samples at seven stations, combined method of wet sieving and sedigraph analysis was used. Granulometric analysis displayed variations in grain size in different seasons. Gravel fraction (particles < 2 mm) was composed dominantly of broken tufa pieces and it was observed that ratio of gravel fraction was lower in May and June, somewhat higher in September and highest during November and December. Accordingly, ratios of sand (2 – 0,063 mm) and mud fraction (silt and clay; < 0,063 mm) were lowest during November and December. During autumn and winter, more intensive rainfall and higher erosion by streams probably washed away loose sandy and muddy particles and only lithified tufa remained on all stations. In warmer and drier months, finer sediment was also present. In order to determine what these fine particles were composed of, the qualitative mineral phase composition by the X-ray diffraction technique was performed on the Philips X'pert powder diffractometer with CuKα radiation. No differences were observed among sampling sites or among sampling seasons. A predominant mineral phase in all samples was calcite. Aside from analysis of a mud fraction, all samples were treated with the hydrochloric acid solution (1:10), drop by drop, in order to remove carbonate component and collect insoluble residue, for further XRD analyses. Quartz was a predominant phase in the residual part of all samples, with micas as probable additional phase, which, due to the small amount was not possible to determine with certainty.

Obtained results suggest that the removal of *Ailanthus altissima* enabled microfauna colonization and re-commencement of tufa formation. We emphasize the need for continuous monitoring, interdisciplinary research and sustainable management of this environmentally sensitive area.

Keywords: tufa, barrier, periphyton, multidisciplinary research, monitoring

An Overview of Tectonic Evolution of the Plitvice Lakes National Park Based on Structural Data

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The Plitvice Lakes National Park (NP) represents a part of the Karst Dinarides, a NW–SE oriented orogenic system parallel to the NE Adriatic coast, formed due to the collision of the Adria Microplate and European Plate during the Eocene and Oligocene. Accommodated collision formed a fold and thrust belt composed of a c. 7 km thick sediment succession (mainly carbonates) deposited on the Adria Microplate during Palaeozoic to Cenozoic time (VLAHOVIĆ et al., 2005). Available data on the present-day stress field show that N- to NNE-directed convergence between European and Adriatic plates is still an ongoing process (average movement between 3 and 4.5 mm/year; GRENERCZY et al., 2005), being a driving force for the differential distribution of horizontal shortening, i.e. compression and transpression in the Dinarides (D'AGOSTINO, 2008 and references therein).

In 2017, the Plitvice Lakes NP initiated a three-year project to improve existing knowledge on the tectonostratigraphic evolution, palaeogeography and Quaternary evolution of the Plitvice Lakes area. In order to evaluate and improve knowledge on the tectonic models and structural framework of the study area a detailed structural investigation was performed within the Mesozoic carbonate units. Structural investigation conveyed detailed outcrop-scale structural analysis, i.e. structural measurements of strata orientation and fault planes as well as determination of the fault kinematics.

During the investigation at 297 sites within the study area 103 measured fault plane data, 250 strata orientation data as well as some overlapping and cross-cutting relations have been collected. On the basis of structural investigation it may be concluded that measured strata orientation in the Plitvice Lakes NP indicate on an asymmetric anticline structure with dominant homoclinal SW limb where strata gently dip (≤20°) towards SW, whereas in the anticline hinge zone (i.e., Plitvice Lakes *"sensu stricto"*) and its steeper NE limb structural measurements pinpoint to strata dipping both towards SW and NE (at angles ≥35°). In the same time, measured and computed fold axial planes are dominantly subvertical and/or steeply dipping towards SW, with characteristic Dinaridic strike (e.g., 135–315°), being associated to the Dinaridic tectonic phase, i.e. NE–SW trending compression. Measured fault plane data within the Cretaceous and Triassic carbonate deposits in the study area may be subdivided into six kinematically compatible fault groups (Fig. 1). These fault groups may reflect three kinematic phases corresponding to the existing structural model of the tectonic evolution of the Dinarides. The oldest

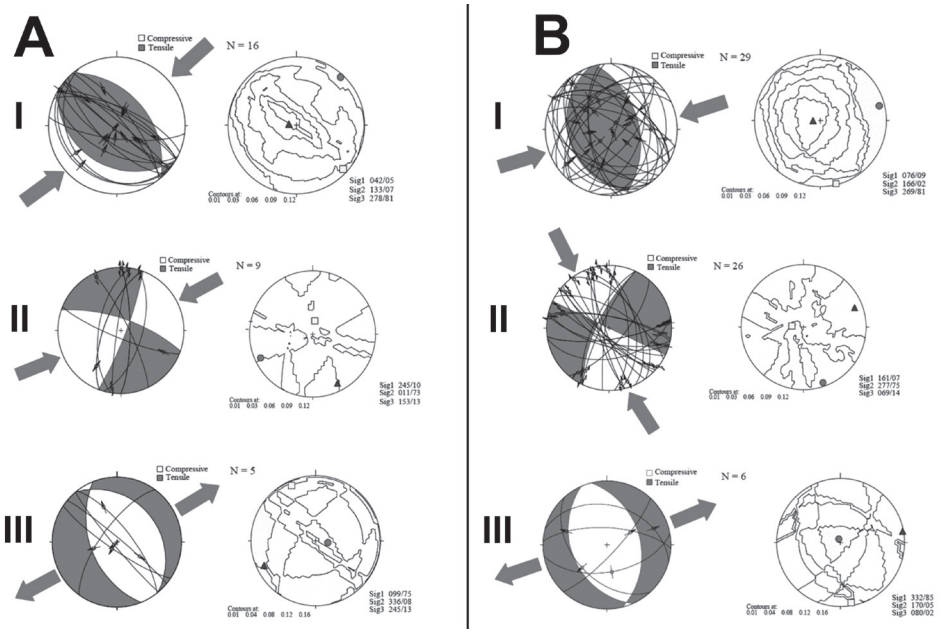

Figure 1. Structural diagrams for the mapped fault planes within the Plitvice fault zone (A), and Cretaceous succession within the footwall area (B). White quadrants on the structural beach-ball diagrams represent compressional while the grey quadrants represent tensional. From top to bottom – reverse faults groups (I), strike-slip faults groups (II) and normal faults groups (III). The red dot indicate σ_1, rectangle σ_2 and blue triangle σ_3.

fault kinematic groups are characterized by NW-SE striking fault dataset, which indicate NE-SW trending compression in the study area. Although measured fault planes (Fig. 1A-I and 1B-I) mostly show typical SW-vergent Dinaridic fault structures, in the area of the Plitvice fault NE-vergent reverse fault planes are more common. In the same time, based on observed cross-cutting relations in respect to the older reverse faults; the younger fault kinematic groups in the study area convey NW and NE-striking dextral and sinistral fault planes (Fig. 1A-II and 1B-II). Observed transpressional/transtensional structures are associated to both NE- and NW-trending transpression/transtension in the area, which probably correlate to the repeated change of the stress field in the post-Dinaridic tectonic phase, i.e. during the Neogene and Quaternary, with tectonic movements along both structurally reactivated and newly formed fault planes. The least observed fault planes in the study area are characterized by NW-SE striking normal fault planes (Figs. 1A-III and 1B-III) indicating NE–SW trending extension within the study area. Though cross-cut relations of normal faults in respect to reverse and strike-slip faults were not observable in the study area, existing kinematic models of faulting in the fold hinge zones (TAVANI et al., 2012) suggest that extensional structures in the fold hinge zone are probably associated to differential stress distribution and accordingly convey extension through collapse perpendicular to the fold's axial plane.

Structural investigation presented here is in agreement with the existing tectonic models of the Dinaridic evolution, although collected structural data in the area of the Plitvice Lakes NP indicate existence of a gentle, large-scale asymmetric NE-vergent anticline above the SW-dipping thrust fault (Plitvice fault), which due to densely fractured Cretaceous and Jurassic carbonates in the fault's hanging-wall, enabled substantial erosion in the fold hinge zone and formation of the Plitvice Lakes system in the remaining impermeable Triassic dolomites.

Keywords: *Plitvice Lakes National Park, Dinaridic tectonic phase, compression/transpression, neotectonics, structural beach ball diagrams*

References

D'AGOSTINO, N., AVALLONE, A., CHELONI, D., D'ANASTASIO, E., MANTENUTO, S. & SELVAGGI, G. (2008): Active tectonics of the Adriatic region from GPS and earthquake slip vectors. Journal of Geophysical Research – Solid Earth, 113, B12: B12413.

GRENERCZY, G., SELLA, G., STEIN, S. & KENYERES, A. (2005): Tectonic implications of the GPS velocity field in the northern Adriatic region. Geophysical Research Letters, 32 (L16311), doi:10.1029/2005GL022947.

TAVANI, S., STORTI, F., BAUSÀ, J. & MUÑOZ, A. (2012): Late thrusting extensional collapse at the mountain front of the northern Apennines (Italy). Tectonics, 31, TC4019, 1-17. doi:10.1029/2011TC003059.

VLAHOVIĆ, I., TIŠLJAR, J., VELIĆ, I. & MATIČEC, D. (2005): Evolution of the Adriatic Carbonate Platform: Paleogeography, main events and depositional dynamics. Palaeogeogrpahy, Palaeoclimatology, Palaeoecology, 220, 333-360.

Valorization of the Groundwater Tracing Tests on the Example of Istria

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Groundwater tracing may be defined as an attempt to solve the groundwater-related hydrogeological problems by means of measurements and interpretation of tracer concentrations in groundwater. The main parameters that can be determined are as follows: the origin of groundwater (recharge area), groundwater flow paths, groundwater flow velocity and direction, groundwater residence time, hydrodynamic dispersion, groundwater recharge, and groundwater flow rate (MOSER, 1995).

Although they are also performed in other types of rocks, groundwater tracing tests are one of the basic research methods in karstic areas. Given that about 50% of the land territory of Croatia belongs to the area of the classical karst, the groundwater tracing has a long tradition. Unfortunately, this type of research is not at an expected level, both in the domain of methodology and interpretation of results, as well as in terms of spatial distribution (coverage). This finding is based on the results of the project "Analysis of groundwater tracing tests in the karst area north of the Zrmanja River", financed by Croatian Waters. For the illustration of the level and value (reliability) of the results obtained so far in this paper, the area of Istria is treated.

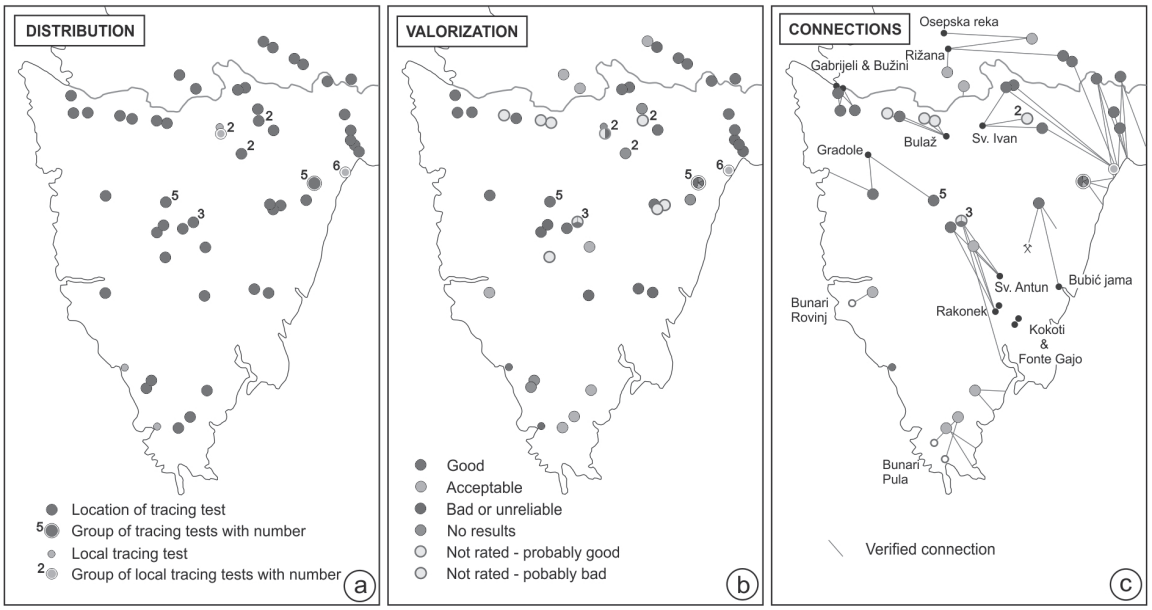

Figure 1. Tracing tests conducted in the wider area of Istria a) distribution b) valorization and c) verified ground water connections.

The first documented tracing experiments in the Istria were performed in 1930 in the area of the spring Sv. Ivan near Buzet (VERONESE, 1939). Although they did not give any significant results, they are likely to be the first tracing tests in Croatia.

Based on the collected documentation in the Istria area, including the cross-border aquifer area in Slovenia to the north, and the marginal area along the watershed toward the springs of Rijeka east of Preluka, 71 tracing test has been carried out so far (Fig. 1a). Considering the fact that some sites are tested on several occasions (Ponor Čiže – 5 times), as well as the fact that part of the tracing tests is of a very local character (distance to the observed water facilities is about 1 km or less), it follows that in the wider area of Istria 53 locations have been investigated. The highest number of tracer tests was performed only with the purpose of determining flow directions and determining the maximum (fastest) apparent groundwater velocities (qualitative tracing).

Although it can be concluded that this is a significant number of tracing tests carried out, the real situation does not confirm this. Based on the analysis of the original documentation, the tracing tests are divided into five categories (Fig. 1b). For 11 tracing tests no original documentation was found and could not be evaluated. Although their results are used in hydrogeological interpretations it is quite certain that some of them are badly conducted and the results are very questionable. Out of the total number of experiments performed, in 8 cases the tracer was not detected in any of the observed springs. 13 experiments are classified in the category of badly conducted and unreliable tracing tests. The results of these tests are not advisable for hydrogeological interpretations and should be repeated. The results of the 15 tests were considered to be acceptable, primarily in terms of defined groundwater flow directions, although they are not entirely reliable in terms of apparent velocities and concentration of tracers. Repeating these tracing tests would be useful, especially if they are used for delineation of protection zones. In the end, only 24 tracing tests can be considered as well performed and documented (5 of which refer to the Ponor Čiže).

The verified water connections resulting from good and acceptable tracing tests (Fig. 1c) are evidently not sufficient for a satisfactory interpretation of the hydrogeological relations on the Istrian Peninsula, and particularly for a more reliable determination of the catchment areas and protection zones. The source of Sv. Ivan in Buzet is a classic example. According to the hydrological calculations, its catchment area has a surface of 65 km^2 (BONACCI & MAGDALENIĆ, 1993). The potential catchment determined by hydrogeological analysis (KUHTA et al., 2015) is about 157 km^2, while according to the much more conservative approach the area covered by the protection zones of this spring is 346 km^2 (BAČANI, 2003). Similar situation is with the Gradole spring. Furthermore, due to the lack of reliable tracing tests, the barrier function of dolomite and dolomitic breccia of the Lower Cretaceous in Central Istria is steel unknown, as well as the northern boundary of the catchment area of the Pula water supply wells. Likewise, there is very little data to define the catchment areas of significant water supply springs in the area of Eastern Istra (Plomin, Raša Valley, Labin), especially in the context of changes caused by the flooding of coal mines.

It can be concluded that in the area of Istria, and similar situation is in the entire karst region, there is a need to repeat the old and to perform a large number of new tracing tests. In this context, the progress of the tracing technique should be applied and the standards of quantitative interpretation finally introduced.

Keywords: tracing tests, valorization, Istria, Croatia

References

BAČANI, A. (2003): Istraživanja u cilju zaštite izvorišta vodoopskrbe na području istarskog poluotoka [Investigations with the aim of protection of the water supply sources in the Istrian peninsula – in Croatian]. Unpubl. Professional report, RGN Faculty, University of Zagreb, 123 p.

BONACCI, O. & MAGDALENIĆ, A. (1996): The catchment area of the Sv. Ivan karst spring in Istria. Ground Water, 31/5, 767-773.

KUHTA, M., BRKIĆ, Ž., LARVA, O. & DOLIĆ, M. (2015): Održivo upravljanje prekograničnim podzemnim vodama između Tršćanskog i Kvarnerskog zaljeva [Sustainable transboundary groundwater resources management between gulfs of Trieste and Kvarner – in Croatian, with an English Extended Abstract]. Unpubl. Professional Report, Croatian Geological Survey, 205 p.

MOSER, H. (1995): Groundwater tracing. In: LEIBUNDGUT, C. (ed.): Symposium H4 held at the XXI General Assembly of the International Union of Geodesy and Geophysics. July, 1995, Boulder, Colorado. Proceedings. IAHS Press, Institute of Hydrology, Wallingford, UK, 119-124.

VERONESE, G. (1939): Appunti perr la storia del Gran de acquetotto Istriano. III Progetto esecutivo – I Lotto, Societa cooperativa topografica, Padova.

First Direct Evidence of Jurassic Evolution of the Central Adriatic Basin Based on Radiolarian Biostratigraphy

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Palagruža is an isolated group of islets (small archipelago) situated in the central Adriatic Sea (Croatia, northern Mediterranean) and represents a central part of the common Adriatic foreland of the Dinaridic and Apenninic orogenic belts (SCISCIANI & CALAMITA, 2009). On palaeogeographic maps this area appears within the Adriatic Basin, situated between Apulia and Adriatic carbonate platforms (GELLETI et al., 2008). Mesozoic pelagic successions of the central Adriatic Basin are buried today beneath Cenozoic deposits and the Adriatic Sea, and are known only from boreholes and seismic profiles. Because of active diapirism in the region (GELLETI et al., 2008), Palagruža is the only place where some of these units are exposed above sea level (KORBAR et al., 2009, 2012). However, because of their distance from the mainland, steep slopes and rocky coast, access to these islets is difficult and information about their geology is still sparse. Here we present the first preliminary results on stratigraphy based on radiolarians from Mala Palagruža islet.

Figure 1. Outcrop photograph of the pelagic succession of Mala Palagruža (Central Adriatic, Croatia). (Photo: T. Korbar, 2007)

The islet of Mala Palagruža is built predominantly of unique succession of thin-bedded siliceous dolomites alternating with chert (Fig. 1) that is recognized as a specific lithostratigraphical unit – Mala Palagruža formation, tentatively assigned to a late Triassic to early Jurassic age (KORBAR et al., 2012). Based on correlation with southwestern Apennines proximal or transitional carbonate platform-to-basin environment is suggested for these deposits.

During this research poorly preserved radiolarian fauna was extracted from a chert sample after treatment with diluted hydrofluoric acid (HF 5%). Identified radiolarians indicate Middle Jurassic age for this sample according to zonation by BAUMGARTNER et al. (1995) based on Uni-

tary Associations (UA). Maximum range of the sample is late Bajocian (UA Zone 4) to late Bathonian-early Callovian (UA Zone 7) defined by the presence of *Protunuma turbo* MATSUOKA. *Stichomitra*(?) *takanoensis* AITA and *Dictyomitrella*(?) *kamoensis* MIZUTANI & KIDO, associated in the sample, both also have their last appearance in UA Zone 7, giving further proof that the sample can not be younger than late Bathonian-early Callovian. A more precise age constraint is not possible because of poor preservation of radiolarians.

These new data provide a rare insight into poorly known stratigraphy of the deeply buried early Adriatic Basin succession and its Jurassic evolution.

Keywords: *Radiolarians, Jurassic, Palagruža, Adriatic Basin*

References

BAUMGARTNER, P.O., BARTOLINI, A., CARTER, E.S., CONTI, M., CORTESE, G., DANELIAN, T., De WEVER, P., DUMITRICA, P., DUMITRICA-JUD, R., GORIČAN, Š., GUEX, J., HULL, D.M., KITO, N., MARCUCCI, M., MATSUOKA, A., MURCHEY, B., O'DOGHERTY, L., SAVARY, J., VISHNEVSKAYA, V., WIDZ, D. & YAO, A. (1995): Middle Jurassic to Early Cretaceous radiolarian biochronology of Tethys based on Unitary Associations. In: BAUMGARTNER, P.O., O'DOGHERTY, L., GORIČAN, Š., URQUHART, E., PILLEVUIT, A. & De WEVER, P. (eds.): Middle Jurassic to Lower Cretaceous Radiolaria of Tethys: Occurrences, Systematics, Biochronology. Mémoires de Géologie (Lausanne), 23, 1013-1038.

GELETTI, R., DEL BEN, A., BUSETTI, M., RAMELLA, R. & VOLPI, V. (2008): Gas seeps linked to salt structures in the Central Adriatic Sea. Basin Research, 20, 473-487.

KORBAR, T., MONTANARI, A., KOCH, G., MARIANI, S., DEPAOLO, D., TURCHYN, V.A., MIKNIĆ, M. & TARI, V. (2009): Geologic reconnaissance of the island of Velika Palagruža (central Adriatic, Croatia). Geologia Croatica, 62/2, 75-94.

KORBAR, T., BELAK, M., FUČEK, L., HUSINEC, A., OŠTRIĆ, N., PALENIK, D. & VLAHOVIĆ, I. (2012): Basic Geological Map of the Republic of Croatia, scale 1:50.000 – sheet Vis-3 and Biševo-1, Croatian Geological Survey (Department of Geology), Zagreb. ISBN: 978-953-6907-27-4, http://www.hgi-cgs.hr/ogk50/vis.html

SCISCIANI, V. & CALAMITA, F. (2009): Active intraplate deformation within Adria: examples from the Adriatic region. Tectonophysics, 476/1-2, 57-72.

Geological Survey of Miljacka 1-5 Cave System

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Miljacka 1-5 cave system is located within the borders of the Krka National Park whose entrance is situated at the right bank of the Krka river, 115 m above sea level. Relatively well-known cave system Miljacka 1-5 is predominantly horizontal with significant hydrogeological function. The most recent explored length of the cave system is 1530 m. However, geological data from the cave are scarce, because no detailed geological surveys have been carried out through the whole length of the cave so far. The cave is developed in the lower part of syncline striking NW-SE in Eocene-Oligocene Promina beds (GRIMANI et al., 1972). According to previous geological data from the surrounding surface area, it is most likely that Miljacka 1-5 cave system is developed between two informal lithostratigraphic units, Miljacka Fm. and underlying Modrino Fm. (MRINJEK, 2008).

The aim of this research was reconstruction of geological relations, and their interconnection with morphology of the cave channels. In that order, ten detailed morphological cross sections were recorded together with detailed sedimentological columns. Morphological cross sections of the cave channels were recorded using the Disto X310 laser distance measure modified for cave measurements, coupled with the PDA device and the PocketTopo software to store and manage measured data and to draw sketches (HEEB, 2008). Sedimentological columns were measured according to standard field procedure (TUCKER, 2011), and sampled for further micropetrographic analyses.

First results indicating, that most of cave channels were developed in the contact zones between two main lithofacies units: clast-supported conglomerates and laminated fine-grained calcarenites with calcilutites and conglomerates (Fig. 1). Contact zone between these two units is marked with a thin layer of coal and clay with high content of organic matter, thus representing zone most prone to dissolution and erosion.

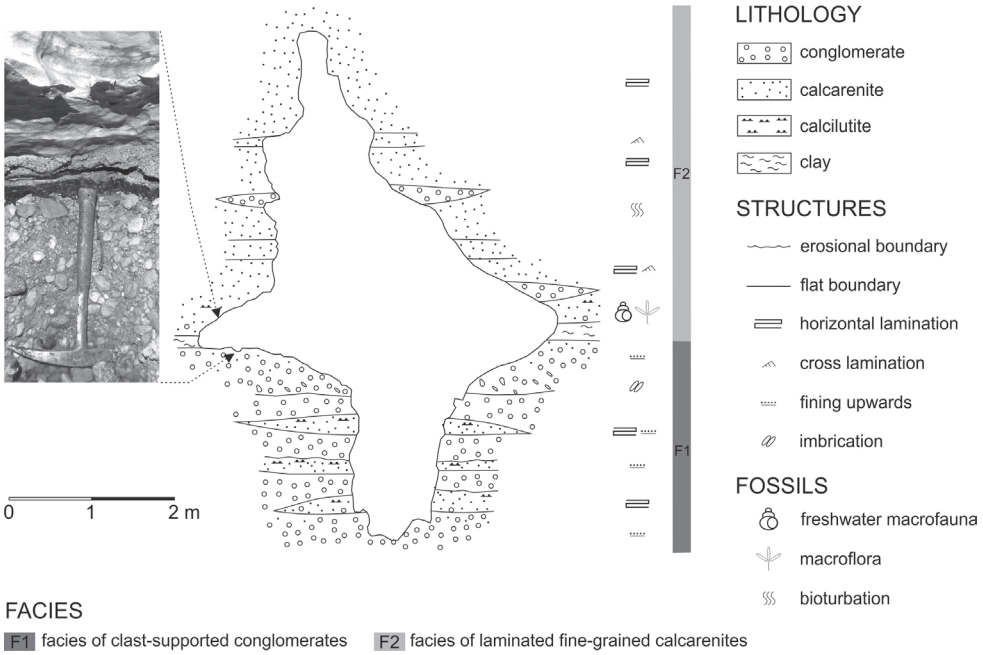

Figure 1. Cross section M1-PP5. Example of interconnection of the cave channel morphology and lithology of host rock.

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Keywords: *Cave Miljacka 1-5, lithofacies, cave morphology*

References

HEEB, B. (2008): Paperless Caving – An Electronic Cave Surveying System. Proc. of the IV European Speleological Congress 2008, 130-133. http://paperless.bheeb.ch.

GRIMANI, I., ŠIKIĆ, K. & ŠIMUNIĆ, A. (1972): Osnovna geološka karta SFRJ 1:100.000, List Knin L33–141. Institut za geološka istraživanja, Zagreb (1962–1966); Savezni geološki institute Beograd.

MRINJEK, E. (2008): The Promina beds in canyon of Krka River and Bribirske Mostine. In: MARJANAC, T. (ed.): Guidebook, 5th ProGEO International Symposium, Rab Island, Croatia. Progeo – Croatia, 2008, 37-77, Zagreb.

TUCKER, M.E. (2011): Sedimentary Rocks in the Field: A Practical Guide. John Wiley and Sons Ltd, Hoboken, 288 p.

Carbonate Platforms in the Adria Plate

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Since the Norian age the Adria was mainly affected by a shallow water deposition which was partially drowned during the extensional tectonics occurred in the Liassic time. Alternation of basin and shallow water domains differently persisted until Cenozoic, originating pelagic sedimentary sequences laterally changing to thick carbonate platforms (CATI et al., 1987; ZAPATERRA, 1994; NICOLAI & GAMBINI, 2007; GRANDIĆ, 2009; DEL BEN et al., 2015).

Since the Cretaceous until Present, the Adria Plate has represented the foreland of Southern Alps, Dinaric/Hellenic and Apennine Chains, producing a bending below the frontal thrusts from the Po Plain to the Ionian Islands, with large sedimentary covers in the diachronous foredeep basins following a forebulge phase.

Several data testify that the Mesozoic sedimentary units and the related, more or less thinned lower crust, represent

different thicknesses and strength opposing to the fronts migration (DEL BEN et al., 2010, 2015). This constrained the migration of deformation and modelled the shape and uplift of the chains.

The PhD research of the first author will focus on the distribution of shallow water and pelagic domains in the Adria plate and on their effect on the compressive deformations in the region. First of all, we have synthetized the literature data focused on these topics. The aim is to compare the different crustal conditions of the foreland and its behaviours under the compressional regimes. This analysis would require integration of Italian data from the western side of the Adriatic (several seismic profiles and boreholes are available from hydrocarbon exploration) with information about the eastern side of the Adriatic Sea, currently mainly represented by the Grandić's papers: collaboration with groups working on the eastern side of the Adriatic are welcome and precious for the PhD research.

Keywords: *Adriatic Plate, carbonate platforms, pelagic basins, platform margin, seismic reflection*

References

CATI, A., SARTORIO, D. & VENTURINI, S. (1987): Carbonate plaforms in the subsurface of the Northern Adriatic Sea. In: CARULLI, G.B., CUCCHI, F. & PIRINI RADRIZZANI, C. (eds.): Evolution of the Karstic carbonate platform: relation with other periadriatic carbonate platforms. Mem. Soc. Geol. It., 40, 295-308.

DEL BEN, A., GELETTI, R. & MOCNIK, A. (2010): Relation between recent tectonics and inherited Mesozoic structures of the Central-southern Adria Plate. Bollettino di Geofisica Teorica e Applicata, 51, 99-115.

DEL BEN, A., MOCNIK, A., VOLPI, V. & KARVELIS, P. (2015): Old domains in the South Adria plate and their relationship with the West Hellenic front. Journal of Geodynamics, 89, 15-28.

GRANDIĆ, S. (2009): Periplatform clastics of Crotian offshore and their petroleum geological significance. Nafta, 60, 503-511.

NICOLAI, C. & GAMBINI, R. (2007): Structural architecture of the Adria platform-and-basin system. Italian Journal of Geology, Spec. Issue No. 7, 21-37.

ZAPATERRA, E. (1994): Source rock distribution model of the Periadriatic region. AAPG Bull., 78/3, 333-354.

Structural Analysis and Impact of Natural Fracturing on Reservoir Properties – Case of the Hamra Quartzites Tight Reservoir in The Hamra II Perimeter (Illizi-Basin-Algeria)

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To renew national reserves and guarantee the country's economic growth, the national oil company SONATRACH is stepping up its research and exploration efforts in the Algerian mining sector. These efforts concern both conventional and unconventional hydrocarbon reservoirs such as shale gas and tight reservoirs (MACÉ, 2008). The Hamra II perimeter is located in the eastern Sahara (Fig. 1) towards the west center of the Saharan East syncline, also called Berkine-Illizi province. It belongs to the northwestern part of the Illizi basin. Geographically, it is delimited by latitudes: 28°45'0''N; 29°25'0''N and longitudes: 6°30'0''E; 7°0'0''E (see the figure). Indeed, in the Hamra II perimeter, Quartzites reservoir Hamra is considered tight (NELSON, 2001), as is the case throughout the Saharan Platform. This reservoir with low porosity and low permeability, has a petroleum potential that is mainly a function of the network of natural fractures. Fracture networks increase the effective permeability that improves the productivity of this type of reservoir (KENANE & LOUMI, 2019). Well tests revealed varying results. There are dry wells, negative wells that have not recorded any hydrocarbon flow at the surface despite the interesting zones identified by the well logs and positive wells with low flow but it is improved flow after stimulation. In the present work, the tectonic structuring phases and their effects on the Hamra Quartzites reservoir in the study area are described. An attempt is made to estimate the impact of natural fracturing on reservoir performance and to explain well test results (ANTONELLINI & AYDIN, 1995).

To achieve these goals, several tasks were performed:

– A structural study based on the analysis of three seismic profiles and the isobath map at the top of the reservoir to trace the tectonic history (LOUMI et al., 2019) and to define the brittle deformations that could influence petrophysical characteristics.

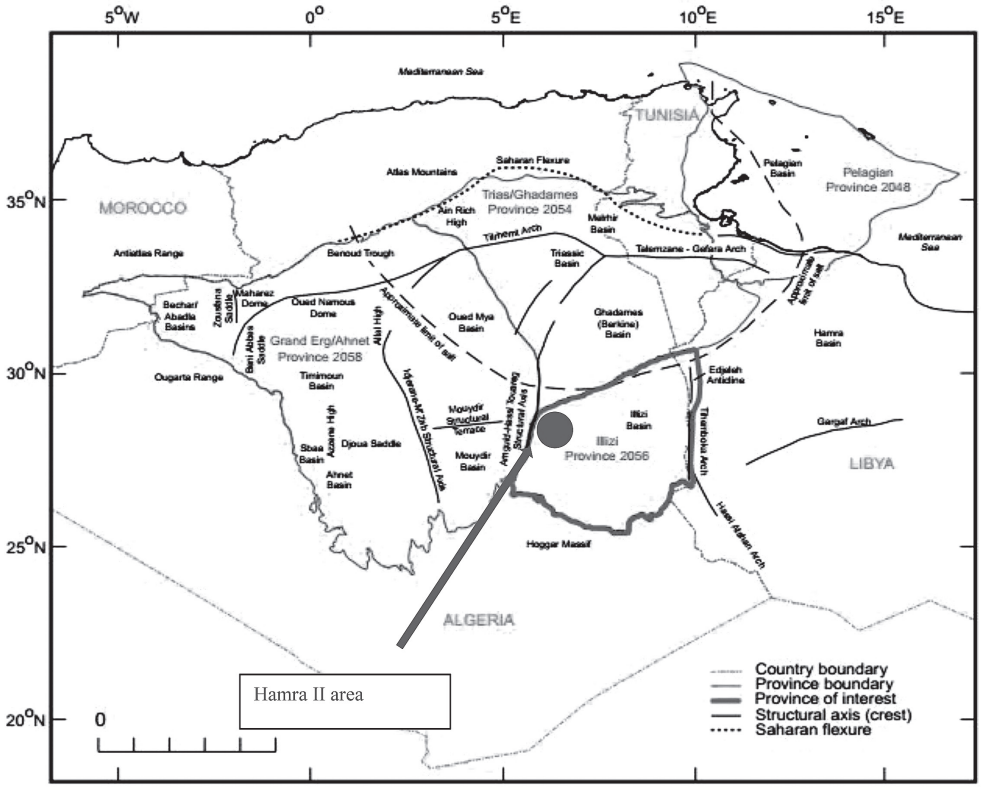

Figure 1. North-central Africa map showing geologic provinces and major structures. The Hamra area is located in the NW of the Illizi Province (KLETT, 2000).

– A study of natural fracturing from well imaging logs (in three wells) to estimate the fracture density its dynamic behavior that will influence the production (ODLING et al., 1999).

– A petrophysical study (in five wells) to determine the nature and distribution of porosity and permeability as well as the reservoir heterogeneity.

Keywords: *Seismic interpretation, Structure maps, Fault systems, Imaging logs, Permeability*

References

ANTONELLINI, M. & AYDIN, A. (1995): Effect of faulting on fluid flow in porous sandstones: geometry and spatial distribution. AAPG Bulletin, 79, 642-671.

KENANE, S. & LOUMI, K. (2019): Spatial organization of natural fracturing in the Boussaada region. Algeria. The 8th international symposium on hydrocarbons and chemistry ISHC8.2019.

KLETT, T.R. (2000): Total Petroleum Systems of the Illizi Province, Algeria and Libya-Tanezzuft-Illizi. U.S. Geological Survey Bulletin 2202–A, Denver, Colorado.

LOUMI, K., MERZOUGUI, R., OUCHAOU, R. & GOUCEM, A. (2019): Impact of faults on the vertical distribution of hydrocarbons in a real case: the filling of the Fersigan of the Taoudenni Basin (Algeria). The 8th international symposium on hydrocarbons and chemistry ISHC8.2019.

MACE, L. (2008): Caractérisation et modélisation numériques tridimensionnelles des réseaux de fractures naturelles – Application au cas des réservoirs. Thèse de Doctorat, Institut National Polytechnique de Lorraine, France, 172 p.

NELSON, R.A. (2001): Geologic Analysis of Naturally Fractured Reservoirs. Gulf Professional Publishing Editions, Houston, 350 p.

Tracing Provenance and Weathering Degree of Modern Sava River Fine-Grained Sediments in Upper Catchment Area

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Sediment fingerprinting becomes increasingly used technique in understanding erosion processes and sediment routing pathways in modern rivers (VEZZOLI et al., 2004; STUTENBECKER et al., 2018). As a result of different processes (chemical weathering, sediment erosion, hydrodynamic sorting and anthropogenic influences) particles accumulate in the sediment as a mixture of all source areas in the basin. Knowing their physical or chemical properties, their relative contributions from sources to sediment mixture can be calculated using inverse or unmixing model (WELTJE, 2012). This method is very suitable in orogenic belts and regions with lack of strong chemical weathering which may obscure the accurate determination of provenance. When we deal with regional scale catchment area, it is important to be cautious because sediment fingerprinting based on tracing individual lithology can give misleading results. It turned out better option to be focused on tributary sampling, which relies on the assumption that a sediment sampled at the end of a tributary represents mixture of all upstream lithologies (GARZANTI et al., 2012). In this way we overcome problems caused by local lithological dissimilarities and focus on large tectonic units. In the upper Sava River catchment, tectonic architecture can be related with main tributary basins: Sava Bohinjka and Sava Dolinka (upstream from Jesenice) basins represent tectonic unit of Southern Alps; Tržiška Bistrica, Kokra, Kamniška Bistrica and Ljubljanica represent sub-tectonic unit of Neogene, which consists of Neogene fresh water basins within large Ljubljana Basin (MIOČ et al., 2003), and Sava Depression along the line Krško-Zagreb (ŠIKIĆ et al., 1979); Savinja (upstream from Celje), Sutla and Krapina represent tectonic unit of Pannonian Basin, while only the Sora River represents the Paleozoic sub-tectonic unit. In order to ensure pure end members fingerprinting, tributaries should preferably drain only one of the four mentioned tectonic units. To compute end member contributions, a standard linear multivariate mixing model FingerPro (CRAN; LIZAGA et al., 2018) was employed. Using different input tracers, the Neogene sub-tectonic unit came out as a most probable source of fine-grained sediments (51.7–64.4 %). Besides, model performance is validated by calculating source contributions for sediment samples at the different mainstem locations. This allows us to examine whether our model has geologically plausible explanation.

As a result of a large amount of rainfalls, steep slopes, and frequent erosions of the material, deeper soil development is disabled in the Sava River headwaters area. The A–CN–K ternary diagram is widely used to illustrate and indicate these processes. Weathering trend of the A–CN–K ternary diagram highlights process of plagioclase chemical weathering and its transformation to illite what is corraborated by illite dominance among clay minerals. Weathering proxies such as conventional (CIA, CPA and CIX) and $\alpha^{Al}E$ indices indicated incipient silicate weathering. Relative order of elements mobility in fine-grained sediments – Na > Sr ≈ Ba > K > Rb > Mg > Ca – is not solely weathering dependent as great influence of provenance and grain-size is also evidenced.

Keywords: *sediment fingerprinting, provenance, chemical weathering, Sava River*

References

GARZANTI, E., RESENTINI, A., VEZZOLI, G., ANDÒ, S., MALUSÀ, M.G. & PADOAN, M. (2012): Forward compositional modelling of Alpine orogenic sediments. Sedimentary Geology, 280, 149-164.

LIZAGA, I., LATORRE, B., GASPAR, L. & NAVAS, A. (2018): fingerPro: An R Package for Sediment Source Tracing. https://doi.org/10.5281/zenodo.1402029.

MIOČ, P. (2003) Outline of the geology of Slovenia. Acta Geologica Hungarica (Budapest), 46/1: 3-27.

STUTENBECKER, L., DELUNEL, R., SCHLUNEGGER, F., SILVA, T.A., ŠEGVIĆ, B., GIRARDCLOS, S., BAKKER, M., COSTA, A., LANE, S.N., LOIZEAU, J.-L., MOLNAR, P., AKCAR, N. & CHRISTL, M. (2018): Reduced sediment supply in a fast eroding landscape? A multi-proxy sediment budget of the upper Rhône basin, central alps. Sedimentary Geology, 375, 105-119.

ŠIKIĆ, K., BASCH & O, ŠIMUNIĆ, A. (1979): Geological Map of SFRJ in scale 1:100000. Explanatory booklet to sheet Zagreb. Federal Geological Survey, Beograd.

VEZZOLI, G., GARZANTI, E. & MONGUZZI, S. (2004): Erosion in the Western Alps (Dora Baltea Basin): 1. Quantifying sediment provenance. Sedimentary Geology, 171, 227-246.

WELTJE, G.J. (2012): Quantitative models of sediment generation and provenance: State of the art and future developments. Sedimentary Geology, 280, 4-20.

Emerging Contaminants in Groundwater Environment – boDEREC-CE Project

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The technological development of laboratory instruments and analytical methods combined with the use of innovative approaches bring out a spectrum of new questions and challenges regarding the occurrence of recently unknown or unmonitored anthropogenic sources of aquatic environment's contamination, so-called "Emerging Contaminants" (EC). The majority of these substances, such as a wide range of pharmaceuticals and personal care products (PPCP) find their way into the soil and water through excretion, waste disposal and wastewater, where they are usually present in low concentrations (ng/I to µg/I). Given the lack of knowledge on their ecotoxicity, persistence, transport and fate, EC are not included in regular surface water/groundwater monitoring on EU level, which represents a problem of cross-border concern and should be tackled by strong transnational cooperation of renowned experts and relevant stakeholders. This is where Interreg Central Europe project boDEREC-CE (Board for Detection and Assessment of Pharmaceutical Drug Residues in Drinking Water – Capacity Building for Water Management in Central Europe) steps in, by focusing on the design of an integrated management of waterworks and recommendations for the improvement of existing legislation on drinking and wastewater standards as well as technical solutions. As a project's starting point, a review of state-of-the-art of current practices in relation to EC in the water environment will help to identify relevant types of substances, existing analytical and monitoring techniques, attenuation strategies and approaches on national and transnational level. Afterwards, in eight preselected pilot areas across Central Europe grouped in three clusters (groundwater extraction sites, surface water extraction sites, extraction sites in karstic areas), representing different hydrological systems under various environmental pressures, behaviour of EC, characteristics of the natural attenuation and removal efficacy of different treatment techniques will be thoroughly studied via jointly developed monitoring methodology and common project EC database. Building upon the results of previous successful EU projects, in particular FREEWAT, NORMAN, MARS and GLOBAQUA, boDEREC-CE partners will develop an implementation strategy of a model-based decision making process for EC called "modePROCON", which will be continuously tested and evaluated during stakeholder capacity building workshops. Another main project output will be "wwDEMAST", a framework for decision-making support tool used by waterworks, for selecting the optimal EC treatment method. In order to foster future cooperation and dissemination of boDEREC-CE results on EU level, a Board of experts will be established.

boDEREC-CE project is co-financed under the Interreg Central Europe Programme 2014-2020 priority specific objective „3.1. To improve integrated environmental management capacities for the protection and sustainable use of natural heritage and resources". The project worth € 2.328.140,81, started its 3-year implementation in April 2019 and will gather 12 project partners originating from 7 EU countries (Austria, Czech Republic, Croatia, Germany, Italy, Poland and Slovenia). The Department of Hydrogeology and Engineering Geology of Croatian Geological Survey (HGI-CGS) has in boDEREC-CE project a role of Lead Partner with selected pilot area "Jadro and Žrnovnica springs catchment". Within that pilot, certain particularities of EC occurrence, transport, and behaviour in karst aquifers will be studied, as well. Since Jadro and Žrnovnica catchment is a typical Dinaric karst terrain, autopurfication is quite poor, and interaction of groundwater sampled on springs and in boreholes with surface water of Cetina River will be compared.

Given how HGI-CGS also participates in international Horizon 2020 project GeoTwinn (Strengthening research in the Croatian Geological Survey: Geoscience-Twinning to develop state-of-the-art subsurface modelling capability and scientific impact) which is among else focused on modelling of EC transport in groundwater, a chance for synergy building between these two projects will enable experts to exchange experience and knowledge gained in the field of emerging contaminants.

Keywords: *emerging contaminants, groundwater, karst, modelling, boDEREC-CE*

Traces of the Late Cretaceous to Paleogene Collision in the Dinarides: Evidence From Sandstone Petrography and Geochemistry

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The area linking the Dinarides with the crystalline basement of the Pannonian Basin marks the position of a suture zone between tectonic units derived from Africa and Europe. The final closure of a remnant branch of the Mesozoic Neotethys ocean at the end of the Cretaceous was a precursor to collision and the ensuing main phase of nappe stacking and uplift of the Dinarides in the Paleogene. This important evolutionary phase is recorded within syncollisional basins concentrated along and in the areas adjacent to the Sava zone, a tectonic unit extending along the margin of the present-day northern Dinarides (JELASKA et al., 1969; PAMIĆ et al., 2002). This study of Upper Cretaceous to Paleogene sedimentary rocks exposed in the western segment of the Sava zone and neighboring areas (Zrinska gora Mt., Medvednica Mt., Žumberak Mts., Cetingrad area) aims at constraining the character of the source areas exposed and eroded in the evolving collision zone.

Following a period of tectonic quiescence and widespread deposition of pelagic limestones in the Campanian (BABIĆ & ZUPANIČ, 1976), a relatively rapid increase in siliciclastic influx heralded the advancement of thrusting and flexural foreland formation along the margin of the Adria plate. Arenites within the Campanian to Eocene deposits record multiple 'crystalline' and 'carbonate' sources. Maastrichtian and some of the Paleocene sandstones are dominantly composed of quartz and sedimentary and very low- to low-grade metamorphic lithics, along with mafic lithics. Heavy mineral fraction of these sandstones is typically composed of apatite, zircon, tourmaline, rutile and variable amounts of Cr-spinel. Together with geochemical data, this indicates a mixed felsic-ophiolitic provenance, probably reflecting erosion of thrusted units of the Adria plate. In the Paleocene and Eocene there was an introduction of felsic and mafic volcanic lithoclasts and plutonic/hypabyssal rock fragments, as well as higher-grade metamorphics. Heavy mineral fractions became strongly dominated by epidote group and garnet, while geochemical data indicate a strong felsic signature and a negligible ophiolite contribution. This sediment was likely derived from the erosion of the magmatic arc that formed along the subduction zone of the Adria plate underneath Europe, as well as from metamorphic units exhumed in the accretionary wedge and/or possibly from the Tisza unit of the overriding plate. Calcarenites interbedded with sandstones and marls are composed entirely of bioclasts, including large benthic foraminifera (Lepidorbitoidinae and Clypeorbinae) and fragments of echinoderms (echinoids and crinoids), corallinaceans (mostly Subfamily Melobesioideae) and bryozoans (mostly fragments of erect rigid colonies). These deposits indicate sourcing from shallow marine carbonate environments that are present in the stratigraphic record of the Sava zone and neighboring areas and represent phases of marine transgression along emerging tectonic units uplifted within the collision zone.

Acknowledgements

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Keywords: *provenance, Cretaceous, Paleogene, Internal Dinarides, Sava zone*

References

BABIĆ, Lj. & ZUPANIČ, J. (1976): Sediments and paleogeography of the Globotruncana calcarata zone (Upper Cretaceous) in Banija and Kordun (central Croatia) [in Croatian, with English summary]. Geol. vj., 29, 49-73.

JELASKA, V., BULIĆ, J. & OREŠKI, E. (1969): Stratigraphic model of Eocene flysch sediments in the Banija area [in Croatian, with summary in English]. Geol. vj., 23, 81-94.

PAMIĆ, J. (2002): The Sava-Vardar Zone of the Dinarides and Hellenides versus the Vardar Ocean. Eclogae geol. Helv., 95, 99-113.

Integrated Analysis of Sarmatian Deposits in the Svetonedeljski Breg Area, South-Western Margins of Central Paratethys

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Studied Svetonedeljski breg area is located approximately 20 km SW of Zagreb and Medvednica Mts. During the Sarmatian (Middle Miocene), this area was situated at the south-western margins of the Central Paratethys, geotectonically being a part of the south-west edge of Pannonian Basin System. In Samobor-Sv. Nedelja area the oldest Miocene sediments are the Upper Badenian in age represented by algal limestones and siltose and laminated marls (VRSALJKO et al, 2005).

Sarmatian sediments are represented by laminated marls. Sandstone beds in the lower part consist of biogenic detritus, mainly re-deposited from the Badenian rocks. The total thickness of Sarmatian deposits is approximately 70 m (VRSALJKO et. al., 2005). This work is based on outcrop study. Sediment samples with visible lithological change were collected at three outcrops and analyzed in detailed (composite section thickness 10 m). For micropalaeontological analysis 12 samples were processed by sieving method and prepared for determination. Foraminiferal association is dominated by benthic species, prevalently rotaliids, with small number of miliolids. Spiny *Elphidium* species and the presence of *Anomalinoides dividens* suggest the deposition during the Badenian/Sarmatian transition (FILIPESCU, 2004; VRSALJKO et al., 2005; FILIPESCU et al., 2014). In order to classify the marls, petrographic analysis of thin sections and calcimetry were done. On the basis of these analysis, marly limestone and variety of marls are defined: marl, calcareous marl, sandy marl and argillaceous marl. For palynological analyses 8 rock samples were prepared with standard palynological processing techniques. In the analyzed palynological assemblage fossil remains of dinoflagellate cysts, green algae (Prasinophyceae, *Botryococcus*), as well as pollen and spore grains were found. Based on the palynological association and domination of *Polysphaeridium zoharyi* and *Lingulodinium machaerophorum*, all analyzed samples were aligned to the Sarmatian *Polysphaeridium zoharyi – Lingulodinium machaerophorum* palynological biozone, corresponding to the *Anomalinoides dividens* Zone (BAKRAČ et al., 2012).

In order to evaluate source rock potential of these Sarmatian marly deposits standard organic geochemistry analyses were performed on selected samples. In the selected samples the organic matter content is in range from 0.29 to 0.47% TOCLECO and 0.19 to 0.53% TOCRE, respectively. Organic matter is represented by kerogen type III (HI=75-166 mg HC/g TOC). High oxygen indices values in all samples have pointed out oxidation of organic matter and carbonate decay. The low organic matter content as well as the defined quality of the kerogen has resulted in very low generative potential (S_2<2 mg HC/g of rocks). Sarmatian marls of Svetonedjeljski breg have no source rock characteristics.

Microscopic examinations in transmitted, reflected and blue fluorescent light reveal domination of amorphous organic matter with weak brown fluorescence indicating low generation capabilities and terrestrial origin of the precursor. In maceral composition liptinites (dominantly sporinites, sporadically alginites and dinoflagellates), reworked vitrinites and fusinites are evidenced, as well.

According to the optical and pyrolitical maturity parameters (T_{max} <435 °C, PI <0.05, yellow FC, TAI 1^+ to 2^-, <0.45%Ro) organic matter is immature, in diagenetic stage of thermal transformation.

Based on the integrated analysis, Sarmatian sediments in the Svetonedeljski breg area were deposited in a shallow marine environment, with changes from tidal to the inner shelf, with periodical input of terrigenous material. Depositional environment was oxic and the organic matter could not be preserved.

Keywords: *Svetonedeljski Breg area, Central Paratethys, Sarmatian*

References

BAKRAČ, K., KOCH G. & SREMAC, J (2012): Middle and Late Miocene palynological biozonation of the south-western part of Central Paratethys (Croatia). Geologia Croatica, 65/2, 207-222.

FILIPESCU, S. (2004): *Anomalinoides dividens* bioevent at the Badenian /Sarmatian boundary – a response to paleogeographic and paleoenvironmental changes. Studia Universitatis Babeş-Bolyai, Geologia, XLIX /2, 21-26.

FILIPESCU, S., MICLEA, A., GROSS, M., HARZHAUSER, M., ZÁGORŠEK, K. & CĂTĂLIN JIPA, C. (2014): Early Sarmatian paleoenvironments in the easternmost Pannonian Basin (Borod Depression, Romania) revealed by the micropaleontological data. Geol. Carpatica, 65/1, 67-81.

VRSALJKO, D., PAVELIĆ, D. & BAJRAKTAREVIĆ, Z. (2005): Stratigraphy and Palaeogeography of Miocene Deposits from the Marginal Area of Žumberak Mt. and the Samoborsko Gorje Mts. (Northwestern Croatia). Geologia Croatica, 58/2, 133-150.

Multiproxy Reconstruction of the Middle Miocene Požega Palaeolake in the Southern Pannonian Basin (NE Croatia) Prior to the Badenian Transgression of the Central Paratethys Sea

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The Pannonian Basin of Croatia is the largest back-arc extensional basin on the European continent, located between the Alps, Carpathians and Dinarides. Syn-rift subsidence started at ~18 Ma and predated the onset of the Miocene Climatic Optimum (MCO; 17-14.7 Ma). In this study, we investigate the evolution of the fluvial-lacustrine palaeoenvironment just prior to the transgression of the Central Paratethys Sea. Studies are based on a 17-m-thick section of the Požega palaeolake in the Southern Pannonian Basin using palaeobiological (mollusks, ostracods, palynomorphs, fish otoliths), mineralogical and sedimentological data. Our results reveal fluctuating freshwater and brackish conditions and a pulsating water budget, which we relate to phases in which the basin was, alternatively, hydrologically open and closed.

We infer that the alternating environmental conditions can be best-explained by dry and wet periods, respectively. Droughts produced stagnant conditions, algae overproduction and increased salinity levels, supporting the survival of sporadically invading brackish water species. The wet periods, on the other hand, led to lake highstand episodes, expansion of its area, and to the onset of profundal settings. The lake basin eventually became overfilled and connected through outflowing rivers with the Central Paratethys sea. However, the absence of brackish-marine assemblages in the Požega palaeolake nevertheless indicates that there was no marine water inflow from the Central Paratethys at that time.

Acknowledgements

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Keywords: Central Paratethys, Burdigalian-Langhian, Miocene Climatic Optimum, Palaeogeography, Palaeoecology

References

MANDIC, O., HAJEK-TADESSE, V., BAKRAČ, K., REICHENBACHER, B., GRIZELJ, A. & MIKNIĆ, M. (2019): Multiproxy reconstruction of the middle Miocene Požega palaeolake in the Southern Pannonian Basin (NE Croatia) prior to the Badenian transgression of the Central Paratethys Sea. Palaeogeography, Palaeoclimatology, Palaeoecology, 516, 203-219, DOI: S0031-0182(18)30430-9.

Hydrofracture System in Glaciolacustrine Unit at Novigrad Sea SW Coast, Croatia

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The Middle Pleistocene glaciolacustrine allo--unit of Novigrad Sea coastal section is represented with poorly cemented varved-like calcisiltites and rippled calcarenites (MARJANAC, 2012), though few well-cemented horizons are distinct. This allo-unit extends for about 2 km along the coast and documents glacial recession as well as younger glacial advance.

The hydrofracture system comprises a variety of small-scale faults, folds, disrupted layers and clastic dykes (Fig. 1). All structures occur concentrated in zones up to 2 m wide and up to 3 m visible vertical intervals. Host sediment is locally strongly disturbed and clay beds were broken and discontinued due to the high pressure of escaping water through the sediment. Narrow clastic dykes representing water escape pipes, up to 1 m in length, are locally visible and are filled with sand-size sediment (Fig. 1a). They occur in association with numerous small-scale reverse faults and small-scale folds (Fig. 1b). Laterally, within the same interval occur soft-sediment deformations with characteristic morphology of liquefaction/fluidization-induced seismites (Fig. 1c) found elsewhere in Pleistocene lacustrine sediments (MARJANAC et al., 2001; MORETTI & VAN LOON, 2014; ÜNER, 2014). Hydrofracture dykes of inclined step-like morphology and thin sediment infill occur locally and are best visible in fine-grained intervals while they die out below a coarser grained interval (Fig. 1d).

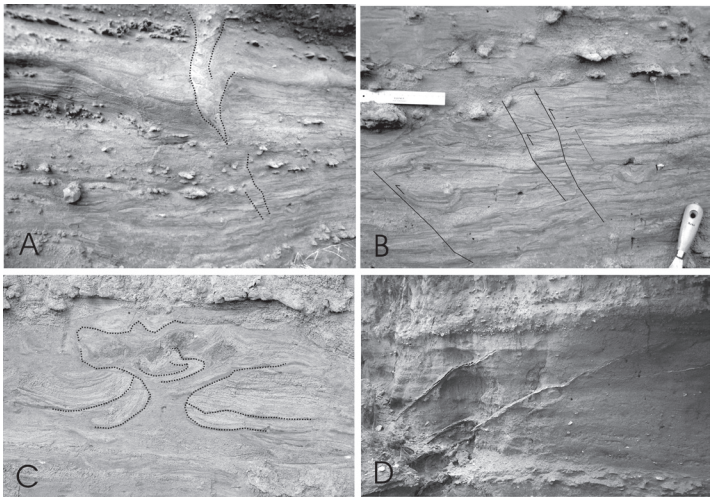

Figure 1. Sediment deformations: A – vertical clastic dyke (enhanced with dotted line) with sediment fill from above; B – small-scale reverse faults and folds occur below the dyke in A; C – mushroom-like soft-sediment deformation with characteristic morphology of liquefaction-induced seismite; D – inclined narrow hydrofracture dykes filled with fine sediment or calcite precipitate.

Hydrofracture systems, in general, resemble water-escape features and „represent a visible expression of the passage of pressurized meltwater through subglacial to ice-marginal environments" (PHILIPS et al, 2013). Nevertheless, this hydrofracture system in the glaciolacustrine unit of Novigrad section is likely not just a result of a significant pressure produced during glacial advance, which is documented by the younger Novigrad moraine (subglacial till) deposited over the glaciolacustrine sediments (MARJANAC, 2012), but also a result of glacioseismic events related to deglaciation.

Keywords: glaciolacustrine deposits, hydrofracture system, Novigrad Sea

References

MARJANAC, Lj. (2012): Glacial and periglacial sediments of Kvarner, Northern Dalmatia and Southern Velebit Mt. Evidence of Dinaric glaciation. Unpublished PhD Thesis, Faculty of Science, University of Zagreb, 278 p.

MARJANAC, T., MARJANAC, LJ., POLJAK, M., ŽIVČIĆ, M. & BAVEC, M. (2001): Serpenica seismites – indicators of paleoseismicity in the Upper Soča valley, NW Slovenia. Geologija, 44/2, 341-350, Ljubljana.

MORETTI, M. & VAN LOON, T. (2014): Restrictions to the application of "diagnostic" criteria for recognizing ancient seismites. Journal of Palaeogeography, 3(2), 162-173.

PHILIPS, E., EVEREST, J. & REEVES, H. (2013): Micromorphological evidence for subglacial multiphase sedimentation and deformation during overpressurized fluid flow associated with hydrofracturing. Boreas, Vol. 42, 395-427.

ÜNER, S. (2014): Seismogenic structures in Quaternary lacustrine deposits of Lake Van (eastern Turkey). Geologos, 20/2, 79-87.

$^{40}Ar/^{39}Ar$ Dating of Tuffs from the North Croatian Basin

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North Croatian Basin (NCB) is located in the Central and Eastern Croatia and represents a south-western part of the Pannonian Basin System. The formation of the NCB commenced 18 million years (Ma) ago and is still lasting today. In this period, except the period of Middle Miocene when it was a part of the Paratethys sea, NCB represented an isolated basin characterized by alluvial, fresh-water and brackish lake deposition (RÖGL, 1996; PAVELIĆ, 2001; PAVELIĆ & KOVAČIĆ, 2018). These periods were characterized by the evolution of endemic species which make the correlation of the beds from the NCB with the beds from the surrounding basins difficult (HARZHAUSER & PILLER, 2007). The most intensive period of volcanic activity was during the Karpatian and the Early and Middle Badenian. Karpatian and Early to Middle Badenian ages are marked by the numerous layers of tuff in the investigated area (PAMIĆ, 1997). Although layers of tuff represent a potential stratigraphic marker, especially in non-marine sediments they haven't been used for this purpose in the NCB. The aim of this research is the reconstruction of the time frame of the evolution of NCB based on the $^{40}Ar^*/^{39}Ar$ dating of the tuffs from different localities and different stratigraphic levels.

Facies analysis and the determined fossil assemblage found in sediments of the investigated area point to fresh-water, brackish and marine depositional environment. The palynomorph assemblages imply that the deposition took place in a moderate to subtropical climate. According to the results of the $^{40}Ar^*/^{39}Ar$ dating on sanidine, tuffs have been dated in the range from 17 Ma to 14.4 Ma (Table 1).

The fossil assemblage of foraminifera, ostracods, nannoplankton and palynomorphs shows that the tuffs older than 15.1 Ma were deposited in freshwater or brackish lake environments, while those dated as 14.8 to 14.4 Ma old were deposited in marine environments.

Formation of the NCB started in Ottnangian with the deposition of coarse grained sediments, dominantly conglomerates intercalated with layers of tuffs in the Kalnik area which have been dated at 18 Ma (MANDIC et al., 2012). Alluvial environments have been gradually replaced with freshwater lake environments. This type of environments lasted up to 15 Ma ago. Layers of tuff found within freshwater lake sediments at the sites of Sjeničak and Paripovac in Banovina area, whose age is determined at approximately 16 Ma (MANDIC et al., 2012) and the tuff determined in the same area at Jovac locality with a determined age of 15.1 Ma confirm that claim. The existence of the freshwater lake environment, with possible marine influences, was also revealed at the locality of Laz on Medvednica Mt. where the age of the tuff was determined at 15.4 Ma. The layers of tuff found within the marine sediments have an age of 14.8 Ma, at the locality of Čučerje-1 on Medvednica Mt. and 14.4 Ma on the locality of Nježić in Slavonija. The mentioned results indicate that the marine transgression in the area of the North Croatian Basin took place around 15 Ma ago, while according to the previous studies (PAVELIĆ, 2001) it was supposed to have started at the beginning of the Karpatian.

Keywords: *$^{40}Ar^*/^{39}Ar$ dating, Miocene, North Croatian Basin, tuffs*

Table 1. $^{40}Ar^*/^{39}Ar$ dating results (Values marked with [*] are from (MANDIC et al., 2012). MSWD – Mean Square Weighted Deviation.

Locality	Environment	Age (Ma)	Deviation [s] (1σ) (Ma)	Nr. of analysis	MSWD
Nježić	Marine	14.40	± 0.03	3/10	2.08
Čučerje-1	Marine	14.81	± 0.08	4/10	1.45
Jovac	Fresh-water	15.10	± 0.06	4/10	0.96
Laz	Fresh-water/brackish	15.42	± 0.15	12/20	1.64
Sjeničak*	Fresh-water	15.91	± 0.06	5/10	1.18
Paripovac*	Fresh-water	16.03	± 0.06	6/9	2.04
Lončarski vis	Unkown	16,96	± 0.03	19/20	2.34

References

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.

MANDIC, O., DE LEEUW, A., BULIĆ, J., KUIPER, K., 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.

PAMIĆ, J. (1997): Vulkanske stijene Savsko-Dravskog međuriječja i Baranje (Hrvatska) [Volcanic rocks of Sava-Drava interfluve and Baranja region (Croatia) – in Croatian]. Nafta., 192 p.

PAVELIĆ, D. (2001): Tectonostratigraphic model for the North Croatian and North Bosnian sector of the Miocene Pannonian Basin System. Basin Research, 13, 359-376.

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.

RÖGL, F. (1996): Stratigraphic correlation of the Paratethys Oligocene and Miocene. Mitteilungen der Gesellschaft der Geologie und Bergbaustudenten Österreich, 41, 65-73.

Latest Maastrichtian to Earliest Palaeocene Platform Carbonates With Coral-Stromatoporoid Patch Reefs, the Island of Brač (Croatia)

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Deposits comprising the Cretaceous–Palaeogene (K/Pg) transition reveal evidence of biotic crisis and one of the most severe global mass extinctions. Studied uppermost Maastrichtian–lowermost Palaeocene (Danian) section on the NW part of the Island of Brač (Likva Cove) comprises shallow marine platform carbonates with continuous K/Pg transition and exceptionally well preserved *in situ* scleractinian coral and stromatoporoid patch reefs.

The Cretaceous part of the section is characterized by co-occurrence of rudists and corals: micritic limestones with rudist and echinoid fragments, ostracods, small benthic foraminifera (discorbids, *Rhapydionina* sp., *Dicyclina* cf. *schlumbergeri*, *Moncharmontia apenninica*, *Laffiteina* sp., *Fleuryana adriatica*) alternate with scleractinian coral and stromatoporoid reef levels, which are poor in other fossil remains. Immediately below the K/Pg boundary, which is already defined by other researchers, last rudists and a concentration of small benthic foraminifera (mostly miliolids) occur. Oldest Palaeocene strata record the input of planktonic foraminifera in otherwise shallow marine micrites with discorbids. The rest of the Palaeocene comprises micrites with ostracods, discorbids, occasional charophyta and *Bangiana hanseni*, which are overlain by the best exposed and biggest patch reef.

Cretaceous and Palaeocene strata show certain differences – shallow marine restricted environments with rudist and bioclastic micrites and tidal flats with laminated fenestral limestones prevail in the Cretaceous, while Palaeocene deposits are characterized by a very shallow restricted marginal marine and freshwater to brackish environments with ostracod-discorbid micrites with charophyta. However, Cretaceous and Palaeocene reef levels are very similar, albeit almost identical. A 50-m-thick succession contains three well-marked and several less prominent reef levels in the Cretaceous part and at the top of the section the most pronounced a single Palaeocene reef level occurs. All four main reef levels formed on top of clear subaerial emersion surfaces indicating that corals and stromatoporoids preferred colonization of hard substrates. Scleractinian corals are present with globular and domal growth forms forming small (up to 2 m in diameter) coral knobs, which formed low relief above the surrounding bottom. Generic determination of corals was not possible due to the intense recrystallization, but they resemble recent finger-like coral colonies such as *Porites* sp. Massive domal and bulbous stromatoporoids occur together with corals, but also individually within the youngest reef level. Wavy-laminar stromatoporoids usually overgrow/encrust(?) coral colonies. Recrystallized micrite, occasionally with very rare ostracods and discorbids, fills the spaces between the knobs. It occurs also as internal sediment partly filling the reef cavities within the youngest reef level, while the rest of the cavities are often filled by botryoidal calcite crystals.

Well-developed coral and stromatoporoid patch reef in the earliest Palaeocene suggests that recovery of reefs was rapid and early, already during the Danian.

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Keywords: *Cretaceous-Palaeogene (K/Pg) transition, corals, stromatoporoids, Brač, Croatia*

Development and Diversity of the *Lithiotis*-type Bivalves in the Lower Jurassic Carbonates of Central and Southern Velebit Mt., Croatia

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Lithiotis-type bivalves are characteristic faunal element of many Lower Jurassic successions in southern Europe, western Arabia, western and central Asia, as well as western margin of North and South America. These large bivalves were most significant buildup-makers in Early Jurassic shallow-marine environments of many Tethyan carbonate platforms.

The study of carbonates with *Lithiotis*-type bivalves was carried out in Central Velebit Mt. (Kubus section) and Southern Velebit Mt. area (Libinje and Mali Alan sections), which are 50 km apart. Benthic foraminifera assemblage (*Lituosepta recoarensis*, *Paleomayncina termieri*, *Lituosepta compressa*, *Orbitopsella primaeva*, *O. praecursor*, *Pseudocyclammina liasica*, *Socotraina serpentina*) indicates Late Sinemurian to earliest Toarcian age. The thickness of sections with *Lithiotis*-type bivalves varies from 210 m on Kubus, to 171 m on Libinje and 145 m on Mali Alan. The oldest *Lithiotis*-type bivalves were found in the lowermost Upper Sinemurian beds at Kubus and youngest in the Lower Toarcian beds at all three sections.

Lithiotis-type bivalve shells mostly occur in micritic limestones indicating growth on muddy substrates in low- to moderate-energy shallow-marine lagoonal environments of the inner carbonate platform. Shells are mostly reworked, and therefore rarely preserved in their primary growth position. All studied sections were characterized by similar shallow-marine environments during the Late Sinemurian and beginning of the Early Pliensbachian. Relative deepening started in late Early Pliensbachian at Kubus (as indicated by occurrence of coarser-grained limestones with slumps), while in Southern Velebit sections shallow marine environments persisted until the latest Pliensbachian. The Pliensbachian-Toarcian transition and earliest Toarcian were characterized by deposition of dark grey micritic limestones with *Lithiotis*-type bivalves and clayey limestones with thin marly beds. Intensely bioturbated micritic limestones, known as "spotted limestones" sharply overlay the last beds with *Lithiotis*-type bivalves and *S. serpentina* indicating middle Early Toarcian age.

Lithiotis-type bivalves are most abundant in the Upper Pliensbachian and lowermost Toarcian deposits in all sections and are generally more frequent in Southern Velebit Mt. Preliminary results show that *Lithioperna scutata* occurred as the first among *Lithiotis*-type bivalves, and is the most common species in the Upper Sinemurian and Lower Pliensbachian beds. First occurrence of *Cochlearites loppianus* can be noticed in the middle Lower Pliensbachian beds. *L. scutata* and *C. loppianus* were equally frequent during the Late Pliensbachian. *Lithiotis problematica* was certainly determined only in the Lower Toarcian beds of the Kubus section. However, most of the Early Toarcian *Lithiotis*-type bivalves cannot be determined on generic level. The trend of increasing shell size is clearly seen in all *Lithiotis*-type bivalves: Late Sinemurian *L. scutata* shells were smaller (average shell length 4–5 cm) comparing to the Pliensbachian ones (9–12 cm) and generally, they are smaller than shells of *C. loppianus*, which measured 15–30 cm in length from the Late Pliensbachian and 25–30 cm from the Toarcian.

Rapid development and wide diversity of these unique bivalves during the Early Jurassic indicate recovery of optimal conditions within shallow-marine environments before their final demise caused by the worldwide early Toarcian Oceanic Anoxic Event (T-OAE).

Keywords: *Lithiotis-type bivalves, Lower Jurassic, Velebit, Croatia*

Petrography of the Upper Miocene Sandstones from the Sava and Drava Depressions: Basis for Understanding the Provenance and Diagenesis of the Largest Hydrocarbon Reservoirs in the North Croatian Basin

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Petrographic analyses are a key method in the study of the genesis of rocks, their mineral composition, textural and structural characteristics. They are the most effective method for understanding origin, erosion, transportation, deposition, and diagenesis of sediments. The subject of this research are the analyses of the Upper Miocene sandstones from selected exploration wells of the Sava and Drava depressions, which to date represent the most important oil and gas reservoirs discovered in Croatia. The Sava and Drava depressions are the biggest depressions of the North Croatian Basin, located in the south-western part of the Pannonian Basin System (PBS), which is surrounded by the Alps, Carpathians and Dinarides, and paleogeographically belongs to the area of Central Paratethys (PAVELIĆ & KOVAČIĆ, 2018, and references therein). The Upper Miocene sandstones are bodies deposited as progradating forms of turbidite systems and delta environments in brackish and partly freshwater lake Pannon, formed after the isolation of Central Paratethys from marine conditions in the Late Miocene (Pannonian) (MAGYAR et al., 1999; SAFTIĆ et al, 2003; KOVAČIĆ & GRIZELJ, 2006; HARZHAUSER & PILLER, 2007; PILLER et al., 2007; PAVELIĆ & KOVAČIĆ, 2018). In this, post-rift, phase in the development of the PBS, thermal subsidence, caused by cooling of the lithosphere, played a significant role (ROYDEN, 1988; TARI et al., 1992).

Petrographic analyses were used to determine the most important factors for reservoir characterization. Determined modal compositions of the analyzed sandstones show no significant differences between the two depressions, and mostly correspond to feldspatho-litho-quartzose types, and rarely to litho-quartzose types (GARZANTI, 2016). Sandstones are largely composed of quartz (monocrystalline and polycrystalline), sedimentary rock fragments (carbonates), feldspar and metamorphic rock fragments. The amount of phyllosilicates (mica) and heavy minerals varies, probably as a result of water energy and individual depositional environment.

The most dominant rock fragments are carbonate fragments, i.e. crystalline dolomites and limestones, recrystallized limestones of mudstone and rarely grainstone type, but also intermittent fragments of bioclasts, such as red algae, resedimented foraminifera shells, as well as mollusks shells. Fragments of siliciclastic sediments, such as mudrocks, mostly marls, and sandstones, which correspond to *rip-up* clasts, as well as volcaniclastic sediments (tuffs) can also be sporadically observed.

On the other hand, metamorphic rock fragments are numerous, including mica schists, quartzites and other fragments of polycrystalline mica, slates, phyllites, but also metasediments, mostly metapelites and rarely metasandstones. Magmatic rock fragments are less prevalent, mostly in the form of plutonic granitoids (granites), and in extremely small quantities altered extrusive rocks. Intergranular volume is in places filled with carbonate cement (calcite and ankerite), fine-grained matrix (a combination of carbonate minerals, quartz, mica and feldspar-plagioclase, formed through alteration and dissolution of main grains) and different types of authigenic clay minerals (kaolinite, illite, chlorite and different types of interstratified clays).

Grain size of the analyzed sandstones is very fine to fine sand. Sandstones are well to moderately sorted, composed of angular to sub-rounded grains, which form tangential (point), and rarely concavo-convex and sutured contacts. Sandstones are mature to submature. Regarding provenance, they belong to recycled orogen, tectonic setting of subduction complex or fold-thrust belt (DICKINSON, 1985). The presence of rock fragments, mostly carbonates and metamorphic schists, implies continental block provenance and axial-belt provenance (GARZANTI, 2016). Heavy mineral association, including, among others, copious amounts of garnet, as well as rutile, tourmaline, apatite, epidote, titanite, but also staurolite and monazite, points towards metamorphic source rocks. Additionally, petrographic analyses enabled the detection of post-depositional processes in sandstones which occurred within the

basin. These changes have the most significant impact on petrophysical parameters of reservoir porosity and permeability. Diagenetic processes of compaction under the pressure caused by burial depth, chemical processes of mineral precipitation (cementation), dissolution of unstable grains and authigenesis of clay minerals have all been detected and described.

The results of petrographic analyses of the Upper Miocene sandstones provided preliminary data for understanding the provenance (origin of detritus and tectonic setting of the source rock) and diagenesis of the sediments. This data can be used for further research and correlation with other sediments deposited in the Late Miocene (Pannonian) in wider area of the PBS, particularly aimed at facilitating research of potential hydrocarbon reservoirs in this region.

Keywords: *Late Miocene (Pannonian), sandstones, petrography, provenance, diagenesis*

References

DICKINSON, W.R. (1985): Interpreting provenance relations from detrital modes of sandstones. In: ZUFFA, G.G. (ed.): Provenance of arenites. Reidel, Dordrecht, NATO ASI Series, 148, 333-361.

GARZANTI, E. (2016): From static to dynamic provenance analysis - Sedimentary petrology upgraded. Sed. Geol., 336, 3-13.

HARZHAUSER, M. & PILLER, W.E. (2007): Benchmark data of a changing sea – palaeogeography, palaeobiogeography and events in the Central Paratethys during the Miocene. Palaeogeogr. Palaeoclimatol. Palaeoecol., 253, 8-31.

KOVAČIĆ, M. & GRIZELJ, A. (2006): Provenance of the Upper Miocene clastic material in the southwestern Pannonian Basin. Geol. Carpath., 57, 495-510.

MAGYAR, I., GEARY, D.H. & MÜLLER, P. (1999): Paleogeographic evolution of the Late Miocene Lake Pannon in central Europe. Palaeogeogr. Palaeoclimatol. Palaeoecol., 147, 151-167.

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, 18, 133-147.

PILLER, W., HARZHAUSER, M. & MANDIC, O. (2007): Miocene Central Paratethys stratigraphy – current status and future directions. Stratigraphy, 4, 151-168.

ROYDEN, L.H. (1988): Late cenozoic tectonics of the Pannonian Basin System. In: ROYDEN, L.H. & HORVÁTH, F. (eds.): The Pannonian Basin. A Study in Basin Evolution. AAPG Mem., 45, 27-48.

SAFTIĆ, B., VELIĆ, J., SZTANÓ, O., JUHÁSZ, GY. & IVKOVIĆ, Ž. (2003): Ternary subsurface facies, source rocks and hydrocarbon reservoirs in the SW part of the Pannonian Basin (northern Croatia and south-western Hungary). Geol. Croat., 56, 101-122.

TARI, G., HORVÁTH, F. & RUMPLER, J. (1992): Styles of extension in the Pannonian Basin. Tectonophysics, 208, 203-219.

The Middle Badenian Deep-Marine Sedimentation in the Central Paratethys: A Case Study of the Sava Depression in the North Croatian Basin

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Continuous rock coring for the purpose of exploring unconventional hydrocarbon reservoirs in the wells of the NW area of the Sava Depression, Croatia, within the SW part of the Pannonian Basin System, has revealed Middle Miocene deep-marine sediments. These sediments indicate deposition in deeper parts of the basin during the Middle Badenian when the Sava depression, together with the remaining parts of the North Croatian Basin (NCB), formed part of the Central Paratethys (PAVELIĆ & KOVAČIĆ, 2018). Since similar sediments rarely appear on the surface in the investigated area, detailed research provided significant information regarding paleoenvironments of the Miocene series, relevant for the interpretation of depositional evolution of the NCB. Most of the sediments consist of marls, interbedded with sandstones.

Detailed mineralogical, petrographic, biostratigraphic, sedimentological and geochemical analyses have been conducted. Marls are fossiliferous, predominantly homogeneous, partly silty and sandy, enriched with organic matter, and interbedded with thin layers of bioturbated sandstones. They are composed of micro- to cryptocrystalline carbonate minerals, primary calcite, and clay minerals, with the ap-

pearance of numerous microfossils and, less frequently, detrital siliciclastic and intrabasinal carbonate grains. The most abundant microfossils are planktonic foraminifera. Sandstones of different types appear as small interbeds. Mixed hybrid sandstones represented by calcarenaceous sandstones and calcarenites are the most abundant, while greywackes are also present. Layers of sand consist of fragments of calcareous red algae (*Corallinaceae*), benthic foraminifera (*Amphistegina* sp., *Elphidium* sp., *Asterigerinata* sp.), bryozoans, molluscs (bivalves) and echinoderms (urchins), appearing as bioclastic detritus, together with other siliciclastic grains (alkali feldspar, plagioclase, quartz, and rock fragments, mostly granitoids). Bioturbation in sediments is represented by traces of short-term infaunal activities of decapod crustaceans (*Thalassinoides*). Some of the most common foraminifera taxa are *Praeorbulina glomerosa* (BLOW), *P. curva* (BLOW), *P. circularis* (BLOW), *Orbulina suturalis* BRÖNNIMANN, *Turborotalita quinqueloba* (NATLAND), *Globigerina concinna* REUSS, *Globigerina tarchanensis* SUBBOTINA & CHUTZIEVA, *Trilobatus trilobus* (REUSS), *Paragloborotalia mayeri* (CUSHMAN & ELLISOR), *Globorotalia bykovae* (AISENSTAT) and *Tenuitella* sp. Determined planktonic foraminifera association implies Middle Badenian age, warm surface water, well-stratified water column and good connections with Mediterranean bioprovinces. Palynological analyses have revealed abundant and heterogeneous dinoflagellate cysts assemblage in which the most frequent and the most important species were *Unipontidinium aquaeductum* (PIASECKI 1980) WRENN 1988, *Hystrichokolpoma rigaudiae* DEFLANDRE & COOKSON 1955, *Systematophora placacantha* (DEFLANDRE & COOKSON 1955) DAVEY et al. 1969, *Melitasphaeridium choanophorum* (DEFLANDRE & COOKSON 1955) HARLAND & HILL 1979, *Polysphaeridium zoharyi* (ROSSIGNOL 1962) BUJAK et al. 1980 and *Palaeocystodinium golzowense* ALBERTI 1961. Index fossil *Unipontidinium aquaeductum* (PIASECKI 1980) WRENN 1988 defines D17-D18 (Uaq and Aan) dinoflagellate cyst biozones (POWELL, 1992) in the Tethyan succession and homonymous zone of the SW part of the Paratethys, specifying Middle Badenian age (15.0-13.4 Ma) (BAKRAČ, 2005). Marls contain organic matter, dispersed and rarely in laminae. Organic carbon content is in the range from 0.40 to 1.81% TOC. Kerogen is dominantly type II. Marls are good source rocks that reached early catagenetic stage of thermal transformation, i.e. the early phase of oil window. Sandstones contain small amounts of kerogen type III. All the facies characteristics of the cored sediments indicate deep-water marine sedimentation, most probably beneath the storm wave-base, on the outer shelf or slope, with occasional material inflow from proximal and shallower areas. Marls were continuously deposited from the suspension in a low water energy environment. Intrabasinal clasts and siliciclastic grains in sandstones and sandy marls, indicate periodic resedimentation from shallower zones caused by storms and turbidity currents. Granitoid orogen most probably spread alongside the shore. The shore was steep and particle transportation from the erosion site to the depositional area was relatively fast, with no major obstacles in shoreface and reef related parts of the basin. Connection with the open sea is indicated by the abundant appearance of planktonic foraminifera, as well as the presence of coccoliths. The deep-marine environment is further confirmed by significant ichnofossil features, as well as considerable pyritization and preserved organic matter, connected to more reductive conditions in the environment.

Keywords: *Central Paratethys, Middle Badenian, deep-marine sediments, Sava depression, hydrocarbon potential*

References

BAKRAČ, K. (2005): Palinološka karakterizacija naslaga srednjeg i gornjeg miocena jugozapadnog dijela panonskog bazena [Palinology of the Middle and Upper Miocene deposits from the south-western parts of the Pannonian Basin – in Croatian, with an English Abstract]. Unpubl. PhD Thesis, Faculty of Science, University of Zagreb, 173 p.

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.

POWELL, A.J. (1992): Dinoflagellate cyst of the Tertiary System. In: POWELL, A.J. (ed.): A Stratigraphic Index of Dinoflagellate Cysts. British Micropaleontological Society, Publication Series, Chapman and Hall, London, 155-229.

WADE, B.S., PEARSON, P.N., BERGGREN, W.A. & PÄLIKE, H. (2011): Review and revision of Cenozoic planktonic foraminiferal biostratigraphy and calibration to the geomagnetic polarity and astronomical time scale. Earth Science Review, 104, 111-142.

New Preliminary Results of the Paleontological Investigations of the Zala Cave Near Ogulin

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Zala Cave, mentioned by Josip Poljak in 1935 by the name Mikašinovića Cave, and also known as Savića Cave, is a speleological object situated northeastward from Ogulin, on the northern slope of the Krpelj hill, on the left side of the Bistrac brook canyon 1.5 km downstream from the spring (geographical coordinates are: 45º 17' 05'' N, 15º 17' 23'' E; 207 m a.s.l.) (ŠOŠIĆ KLINDŽIĆ et al., 2015). Previous archaeological investigations were performed from 2000 to 2011. Faunal remains of medium and large mammals (total taxa number = 18) analysed by RADOVIĆ (2015), show slightly bigger number of taxa determined in the Late Pleistocene deposits (n = 13) compared to those found in the Holocene deposits (n = 11). The following taxa were determined: Leporidae, *Marmota marmota*, *Canis lupus*, *Vulpes vulpes*, *Ursus* sp., *Martes* sp., *Meles meles*, *Felis silvestris*, *Sus scrofa*, *Capreolus capreolus*, *Cervus elaphus*, *Alces alces*, *Rupicapra rupicapra*, *Bos primigenius,* and *Ovis/Capra*. Besides large mammals, small mammal remains have been also found in different layers, which we present here for the first time. These finds were discovered during excavations in 2005, and 2008 till 2011. From a total number of selected remains (NISP = 559) 78 osteo-dental remains were suitable for taxonomic determinations. For arvicolids (subfamily Arvicolinae GRAY, 1821) the most characteristic and useful for the specific determinations are the first lower (m1; NISP = 46) and third upper (M3; NISP = 1) molars, while other taxa were determined on the basis of teeth, but also on other anatomical elements. Representatives of the following orders/families were found in the fossil material: Chiroptera, Eulipotyphla, Cricetidae, Arvicolidae, Muridae, and Gliridae. While they originate from the 11 layers, only for two layers absolute dating is available. The layer 100 is of 14.1±60 ka uncal BP (Beta-334806) age, while the layer 102 has an age of 13.34±60 ka uncal BP (Beta-334805) (ŠOŠIĆ KLINDŽIĆ et al., 2015).

On the basis of selected osteo-dental finds it is possible to conclude that the remains of bat (Chiroptera) and mole (*Talpa* sp.) were found only in the Late Pleistocene layers 100 and 101, while the remains of *Neomys* sp., *Cricetus* sp., *Chionomys nivalis*, Arvicolidae indet., Gliridae indet., and *Apodemus* sp. only in the Holocene layers: 71, 77 and 85. All other taxa have been found in both Late Pleistocene (layers: 13, 97, 100, 101 and 102), and Holocene deposits (layers: 71, 71/89, 77, 82/89, 85, 97/89 and 105), and they are: *Erinaceus roumanicus*, *Arvicola amphibius*, *Myodes glareolus*, *Microtus* ex gr. *arvalis/agrestis*, *M.* ex gr. *subterraneus/multiplex*, *Microtus* sp. and Muridae indet. (Fig. 1).

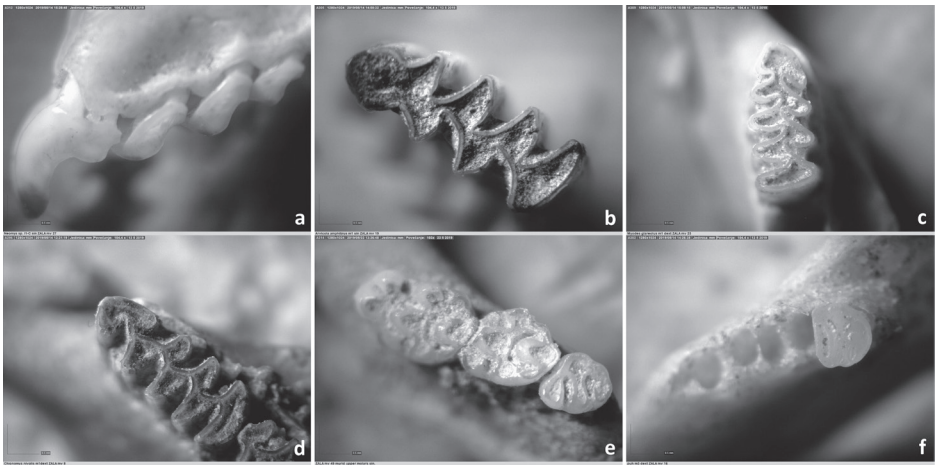

Figure 1. Small mammal finds from the Zala Cave: a – Neomys sp., left premaxilla with first three incisives and canine (I1 – C sin.; buccal side; coll. number: mv 27); b – Arvicola amphibius, first lower left molar (m1 sin.; occlusal; coll. number: mv 19); c – Myodes glareolus, first lower right molar (m1 dext.; occlusal; coll. number: mv 23); d – Chionomys nivalis, first lower right molar (m1 dext.; occlusal; coll. number: mv 8); e – cf. Apodemus sp., upper left molar row (M1-3 sin.; occlusal; to the left: oral side; coll. number: mv 49); f – Gliridae indet., third lower right molar (m3 dext.; occlusal; coll. number: mv 16).

Typical forest dwellers (*Myodes glareolus*, *Erinaceus roumanicus*, glirids, murids) are present in the Holocene deposits. The animals of the open, grassy environments (e.g. *Arvicola amphibius*, *Microtus* ex gr. *arvalis/agrestis*, *Microtus* sp.) are more abundant in the Late Pleistocene layers.

A total of 246 bird (Aves) remains was discovered in the cave deposits. Preliminary results show presence of aquatic taxa (Anseriformes).

Such faunal aggregate refers to the temperate continental climate conditions during the Late/Latest Pleistocene and the beginning of Holocene with open, grassy habitats at the end of Pleistocene, while at the beginning of Holocene forest vegetation started to spread in Europe, and was common environmental characteristic in the vicinity of the Zala Cave as well.

Keywords: *Zala Cave, small mammals, birds, Late Pleistocene/Holocene, palaeoenvironment.*

References

RADOVIĆ, S. (2015): Lov u paleolitiku i mezolitiku: arheozoološka analiza velikih sisavaca iz špilje Zale. In: Arheologija špi-lje Zale, Od paleolitičkih lovaca skupljača do rimskih osvajača. VUKOSAVLJEVIĆ, N. & KARAVANIĆ, I. (eds.): Katedra Čakavskog sabora Modruše, 119-156.

ŠOŠIĆ KLINDŽIĆ, R., KARAVANIĆ, I., VUKOSAVLJEVIĆ, N. & AHERN, J.C.M. (2015): Smještaj, stratigrafija, kronologija i tijek iskopavanja špilje Zale. In: Arheologija špilje Zale, Od paleolitičkih lovaca skupljača do rimskih osvajača. VUKOSAVLJEVIĆ, N. & KARAVANIĆ, I. (Eds.): Katedra Čakavskog sabora Modruše, 15-48.

New Discovered Dinosaur Tracksite in the Late Albian of Istria

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Deposits of the mid-Cretaceous period of Istrian peninsula bear the most abundant record of the dinosaur presence on the Adriatic-Dinaridic carbonate platform. There are many sites with the dinosaur footprints which were found in the sediments that crop out along the shore within the mid-Cretaceous sediments of the so-called West Istrian anticline. The most numerous localities are situated near the town of Pula and Novigrad. The new site was discovered near the city of Novigrad, at the Mareda locality. Regarding the geological map of the area (PLENIČAR et al., 1965) the age of the trackbearing sediment is Late Albian. The outcrop is situated at the sea shore and during the high tide it is partially covered with the sea water. The trackbearing layer is quite eroded due to the seawater abrasion. The Upper Albian carbonate succession at Mareda locality is similar to other Upper Albian localities in Istria. It is characterized by thin bedded limestones deposited in peritidal and foreshore environments with several shallowing-upward sequences.

A dozen of rather shallow footprints have been recognized on the site. The discovered footprints are tridactyl, mesaxonic, longer than wide, with slender digits (Fig. 1). Their state of preservation is far from ideal regarding constant exposure to the seawater. The average length of the footprints is 25 cm and their width 16 cm. On all of the footprints the middle digit is the largest one while the outer two are of similar dimensions and diverging from the print axis. The digits are widest in their middle part and become narrower proximodistally. Sharply curved claw marks are visible on some of the digits. Around some footprints there is a clearly pronounced expulsion rim which resulted from the placing of the foot in the wet mud. We interpret the footprints as true tracks rather than undertracks although

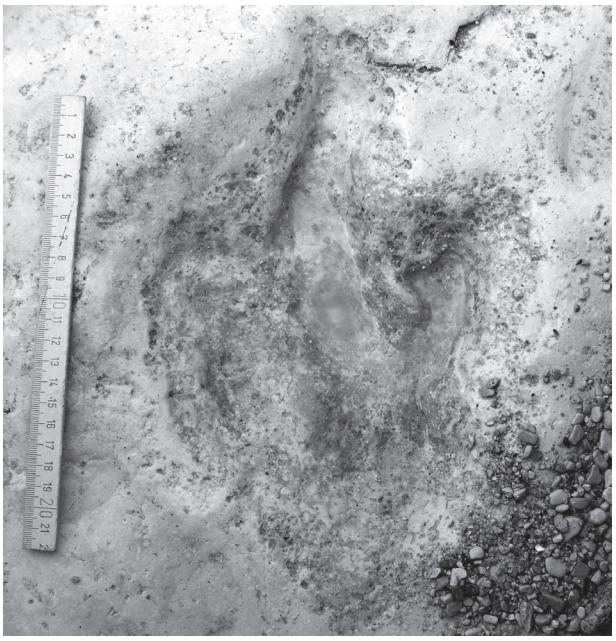

Figure 1. Theropod footprint from the Mareda locality.

they are relatively shallow when compared to its average size. There are no clearly recognizable trackways at the outcrop although there are some series of eroded prints which could hint at such possibility.

On the basis of the claw marks or pointed distal end of digital prints, relatively slender digit impressions and generally longer than wide prints, we conclude that these footprints belongs to a medium-sized bipedal theropod dinosaurs. The Late Albian dinosaur ichnocoenosis from Istria is constituted of mainly theropod but also sauropod and ornithopod footprints found at different localities (MEZGA, 2010). When compared to the other Late Albian theropod footprints in Istria the footprints from Mareda locality most closely resemble to the footprints found in the nearby Solaris (DALLA VECCHIA et al., 2000) and Ploče tracksites (MEZGA & BAJRAKTAREVIĆ, 2004) due to its similarity in dimensions and morphology.

Keywords: *Dinosaur footprints, Theropods, Late Albian, Istria*

References

DALLA VECCHIA, F.M. & TARLAO, A. (2000): New Dinosaur track sites in the Albian (Early Cretaceous) of the Istrian Peninsula (Croatia) - Part II – Palaeontology. Memorie di Scienze Geologiche, 52/2, 227-292.

MEZGA, A. (2010): Dinosaur Ichnocoenoses on the Adriatic-Dinaridic Carbonate Platform. In: HORVAT, M. (ed): Abstracts Book – 4 Croatian Geological Congress, Šibenik, Oct. 14-15, 2010, 93-94.

MEZGA, A. & BAJRAKTAREVIĆ, Z. (2004): Cretaceous dinosaur and turtle tracks on the island of Veli Brijun, Istria, Croatia. Geologica Carpathica, 55/5, 355-370.

PLENIČAR, M., POLŠAK, A. & ŠIKIĆ, D. (1965): Basic Geological map 1:100 000, Sheet Trst L33-88. Geološki Zavod Ljubljana i Institut za geološka istraživanja Zagreb (1965), Savezni geološki zavod, Beograd.

Recurrent Events of Dinoturbation in the Early Cretaceous Deposits, Cape Gustinja, Istria

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Cape Gustinja is located on the western coast of Istria, near the Kolone Bay. The outcrops with footprints are located near the shore on the southern side of Cape Gustinja, and the exposed location contributes to destruction and decay of the footprints (both by nature and tourists).

The investigated succession on the Cape Gustinja consists of well-bedded limestones with an average thickness of 20 cm. Since the tracksite is situated at the seaside, during normal tide the water covers some layers that include recognized footprints. Due to the susceptibility of limestone to erosion and seawater corrosion, almost all dinosaur footprints at this site are at least partially damaged, and some are almost unrecognizable. A continuous 20 m-thick section of shallow-water platform carbonates was studied to determine biostratigraphy of microfossil assemblage (benthic foraminifera and calcareous algae) and microfacies. Studied succession indicates deposition within very shallow inner platform environments occasionally interrupted by short lasting subaerial exposures (occasionally short lasting emergent horizon). The main horizon with the dinosaur footprints is composed of wackestone with bioclasts and fenestral laminites deposited in the intertidal environments (Fig. 1). Bioclasts of bivalves, gastropods, ostracods, benthic foraminifers and green algae prevail. The

Figure 1. Dinoturbated layer of intertidal limestone at the Gustinja tracksite.

Late Valanginian – Early Hauterivian age of these deposits is based on their microfossil content, which is dominated by ostracods, benthic foraminifera and calacareous green algae (Dasycladales).

The Cape Gustinja site is unique among the Croatian tracksites characterized by a relatively small area with abundant track horizons in a short time sequence. Track hori-

zons include fossilized dinosaur footprints and dinoturbated layers with dinoturbation in several stratigraphical horizons, sometimes located directly below each other. Layers with dinoturbation are extremely disturbed, the individual footprints and their movement directions are almost impossible to discern, so whole ichnotaxonomic interpretation is based on horizons without dinoturbation. Although the Gustinja site is relatively close (about 900 m) to another dinosaur footprint site (the Palud locality; MEZGA et al., 2015), a fault zone located at the tip of Cape Gustinja separates the two localities and disable the correlation. In the Gustinja Cape carbonate succession eight different horizons with dinosaur footprints and dinoturbation have been identified. More than 50 individual footprints and several trackways are recognized. Two types of tracks can be discerned; circular-elliptical and semi-circular to half-moon forms. Because of this characteristic appearance, and without any apparent more detailed morphology, the footprints are attributed to the sauropod dinosaur, which is in line with earlier research (DALLA VECCHIA et al., 2000). The main trackbearing layer is split into two separate outcrops with a fault between. Dinoturbated layers are placed above the main layer with the footprints, what in the undisturbed sediment sequence means that they are stratigraphically younger. The length of the footprints varies between 30 and 60 cm indicating individuals of different length (up to 20 meters).

Keywords: *Dinosaur footprints, Dinoturbation, Sauropods, Early Cretaceous, Istria*

References

DALLA VECCHIA, F.M., TARLAO, A., TENTOR, M., TUNIS, G. & VENTURINI, S. (2000): First record of Hauterivian dinosaur footprints in southern Istria (Croatia). In: VLAHOVIĆ, I. & BIONDIĆ, R. (eds): Proceedings, Second Croatian Geological Congress, Cavtat, May 17-20, 2000, 143-149.

MEZGA, A., CVETKO TEŠOVIĆ, B., PRETKOVIĆ, V., JOVANOVIĆ, N. & BAJRAKTAREVIĆ, Z. (2015): Dinosaur footprints in the Lower Hauterivian deposits of Palud Cove in Istria, Croatia. Geologia Croatica, 68/2, 113-122.

Detailed Engineering Geological Map of the Podsljeme Urbanized Zone of the City of Zagreb

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For the purpose of producing the detailed maps and identifying the unstable slopes the Detailed Engineering Geological Map (DEGM) of the Podsljeme urbanized zone of the city of Zagreb at the scale 1:5000 was prepared for the area of the southern slopes of Medvednica Mt. The extent of the study area was approximately 175 km^2 (Fig. 1). The DEGM of the Podsljeme urbanised zone was developed within the Phase I (MIKLIN et al., 2007) of the project lasting from 2004 to 2007. Within Phase II (MIKLIN et al., 2018) of the project lasting from 2015 to 2018 the data and maps were updated. The Phase I of the research resulted with the detailed overview of the deposits in two dimensions (2D) and was presented on a geological map at the scale of 1:25000, a hydrogeological map at the scale of 1:25000 and in DEGMs at the scale of 1:5000. During the Phase I a landslide cadastre with database was also created for the study area, with 707 registered landslides.

The main research in the Phase II consisted of subsurface investigations (boreholes) in order to collect data in 3D. The investigations were also carried out in order to collect data on the thickness of the cover on the bedrock, surface weathering zone thickness and to determine geological, engineering geological and geotechnical properties of materials. The investigations were based on the boreholes, additional field mapping, geological, geotechnical, and geophysical research and numerous laboratory analyses. Total of 230 boreholes were made, of which 119 along 14 cross-sections and 111 on the landslides. The borehole data were presented on borehole logs which contained basic information on borehole, technical parameters, engineering geological determination and results of field and laboratory testing. Conducted laboratory tests can be divided in two groups: (i) identification tests with purpose to determine general parameters of soils and rocks; (ii) tests to determine mechanical parameters of soils and rocks. Geophysical method Multichannel Analysis of Surface Waves (MASW) was used to obtain one-dimensional models of change of seismic s-waves velocity with depth. Also, dynamic elasticity modulus, dynamic shear modulus and vs_{30} parameter

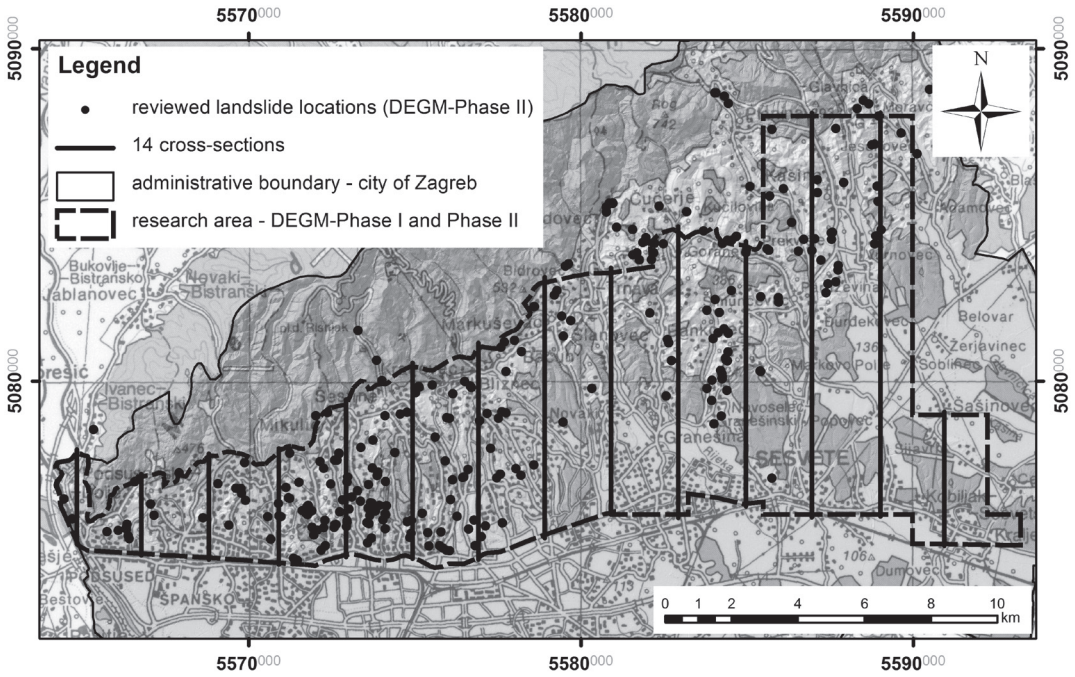

Figure 1. Overview map of conducted research for the Detailed Engineering Geological Map – Phase II.

were calculated. 238 MASW measurements were made approximately on the same cross-sections as the boreholes.

As the results of Phase II, data on landslides were updated (213 landslides were registered or updated and entered into the database) and 14 engineering-geological cross-sections of the study area were developed. Additionally, modifications and updates of existing engineering geological maps at the scale of 1:5000 were carried out. Also the DEGM GIS Project from Phase I was updated with data from Phase II. The research and data collected in DEGM Phase I and Phase II are related to the same study area so the results of Phase I and Phase II complement and improve the data quality for this area and generally provide a better framework for considering existing issues related to the geological, seismic and geotechnical aspects in a wider sense for the Podsljeme urbanized zone of the city of Zagreb.

Keywords: *Podsljeme urbanized zone, Detailed Engineering Geological Map, landslide data base, GIS project*

References

MIKLIN, Ž., MLINAR, Ž., BRKIĆ, Ž. & HEĆIMOVIĆ, I. (2007): Detaljna inženjerskogeološka karta Podsljemenske urbanizirane zone mjerila 1:5000 (DIGK-Faza I) [Detailed engineering geological map of Podsljeme urban area in scale of 1:5000 (Phase I) – In Croatian]. Croatian Geological Survey, Zagreb, Books 1-4, 44 maps.

MIKLIN, Ž., PODOLSZKI, L., NOVOSEL, T., SOKOLIĆ, Ž., OFAK, J., PADOVAN, B. & ZAILAC, K. (2018): Detaljna inženjerskogeološka karta Podsljemenske urbanizirane zone mjerila 1:5000 (DIGK-Faza II) [Detailed engineering geological map of Podsljeme urban area in scale of 1:5000 (Phase II) – In Croatian]. Croatian Geological Survey, Zagreb, Books 1-6, 41 maps.

Historical Mining in Croatia – Valuable Examples for European MineHeritage Project

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MineHeritage – "Tracing and learning from ancient materials and mining technology" is a running Wider Society Learning project with the main goal to raise society's awareness of usage and need for raw materials. Duration of the project is three years (1 January 2019 – 31 December 2021) with total budget of 974,245.00 € founded by European Institute of Innovation & Technology (EIT) in the frame of Knowledge and Innovation Community (KIC) Raw Materials. Project consortium consists of 13 partners from eleven European countries, with Faculty of Mining, Geology and Petroleum Engineering as one of them. Leading partner is New University of Lisbon – Faculty of Sciences and Technology (FCT NOVA) from Portugal.

The scope of the MineHeritage project is wider understanding of the mining technologies and raw materials uses and trades in different regions of Europe during specific historical periods (since prehistory) with the resulting impact on development of European society. The objectives of the projects are following: (1) to engage dissemination approaches to cross-generational target audiences on mining and raw materials as a unifying common ground for Europe through an historical perspective; (2) to promote synergies with other actors such as schools, museums, local administration and mining companies; (3) to involve society in raw materials and mining through knowledge, (4) to build multicultural bridges between different regions in Europe; (5) to stimulate the debate on environmental sustainability in mining and raw materials sector; (6) to develop popular science materials and organise popular science events; and (7) to raise awareness of own cultural heritage and history of a region. End users of the project are school age children (13-19 years) and young adults (20-45 years).

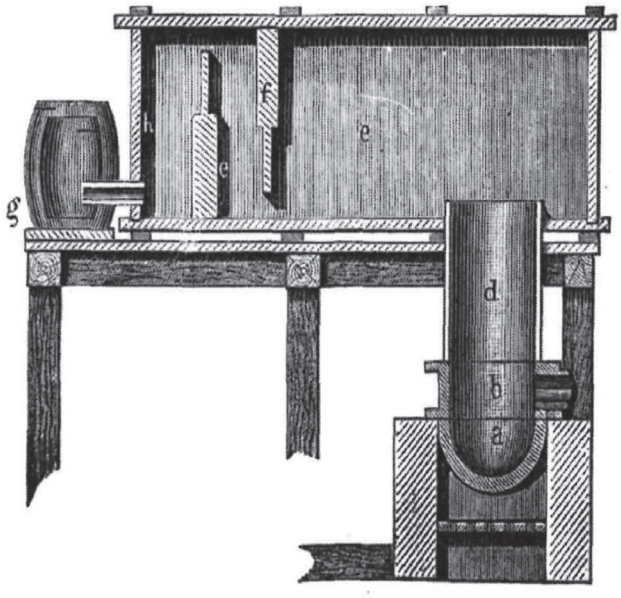

Figure 1. Radoboj machine for sulphur purification (from KIŠPATIĆ & TUĆAN, 1914.)

Expected project outcomes are: (1) database with information on ancient mining sites, abandoned mines, classified heritage sites related to mining from different EU countries participating in the project; (2) popular science materials (booklets and videos on specific mining sites); (3) interactive multilevel game with historical and regional perspective of mining and raw materials in Europe; (4) mobile application for cultural tourism involving historical mining sites; (5) social media accounts (Facebook, Instagram, LinkedIn and YouTube) dedicated to the dissemination of historical mining sites, events and news; (6) promotion of popular science materials (talks, lectures, discussion events, excursions); (7) collaboration with local administration, tourist offices, schools, museums, as well as with other KIC running programs.

The emphasis of the presentation will be on up-to-date information related to Croatian historical mining sites collected for the database, promotional activities of the Croatian team as well as established collaborations. Croatia has a long mining tradition and heritage. Exploitation of natural and crushed stone together with sand and gravel for civil engineering purposes has represented the most important raw material exploited in Croatia throughout our history to the present days. Although, there is no potential in Croatian ore deposits nowadays, there were times in the past when metal production (Ag, Zn, Pb, Cu, Fe) was significant (e.g. Trgovska gora; Rude). There are also several distinct historical mining sites of non-metallic minerals (e.g. sulphur in Radoboj; bauxite in the Mirna valley in Istria). Notwithstanding out of interest for KIC Raw Material, we will present several coal mines, especially when they were related to mining of other commodities (e.g. coal and zinc in Ivanec). Historical examples of technologies related to mining in Croatia will also perfectly contribute to the overall project (e.g. Radoboj machine for sulphur refinement shown on Fig. 1; blast furnace from Bešlinec). Alongside

traditional promotional materials as brochures and videos, important localities will be promoted using geocaches (traditional and EarthCaches).

Acknowledgment

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Keywords: *raw materials, historical mining and processing, heritage*

References

KIŠPATIĆ, M. & TUĆAN, F. (1914): Slike iz rudstva. Matica Hrvatska, Zagreb, 381 p.

SIMONA Project – Transnationally Harmonized Protocol for Drainage Sediment Sampling and Laboratory Analysis of Hazardous Substances Content in Danube River Basin

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The SIMONA project is an Interreg project within the Danube Transnational Programme, which responds to a long needed initiative for accessing data and a development of Sediment-quality Information, MONitoring and Assessment System (SIMONA). The project is designed to ensure support for transnational cooperation in joint Danube Basin water management. The focus of the project is on monitoring of the drainage sediment quality. The Croatian Geological Survey is responsible for Working Package 4 of the project, which outputs were transnationally harmonized protocols for drainage sediment sampling and hazardous substances content laboratory analyses in the Danube basin. These protocols were primarily based on data being collected and inventoried under the Working Package 3 of the project, which included inventory of protocols and methodologies for drainage sediment sampling and analyses in all 17 project partner countries. The first activity within the Working Package 4 was a review of inventoried protocols by the following criteria: the developed protocols (1) are acceptable in all countries of the Danube Transnational Programme, (2) are in-line with the International Commission for the Protection of the Danube River and the EU requirements, (3) are based on the latest scientific knowledge and (4) are sustainable. Within the second activity, protocols were developed for sampling and laboratory analyses of various drainage sediments (bottom, suspended and floodplain).The third activity was focused on reviewing the drafted protocols in terms of comments and suggestions from all project target groups across the whole Danube Basin.

The two working groups Sampling WG and Laboratory WG are responsible for all three activities during period from the 1th of February 2019 to the 1th of October 2019. During protocols development, the WGs also reviewed guidelines from the Water Framework Directive Guidance documents and EU Common Implementation Strategy of Water Framework Directive (CIS WFD), GEMAS (Geochemical Mapping of agricultural and grazing land soil) project, FOREGS (Forum of European Geological Surveys) project and all other relevant studies. In addition, the working groups conducted comprehensive data analysis and organized workshop in Zagreb with all project countries representatives where obstacles and problems were discussed.

Finalization of the protocols ensured uniform and reliable monitoring of the quality of the drainage sediment across the almost whole Danube Basin. Finally, they assured prompt and precise hazardous problem detection and represent first step in protection from unexpected and unwanted negative changes in environment.

Keywords: *SIMONA project, monitoring, drainage sediment, hazardous substances*

3D Modeling from the Morphotectonic Study and the 2D Seismic Interpretation of the Southern Part of the Medina Sinclinorio, Piedemonte Llanero, Colombia

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Medina Synclinory, locate in the Eastern Foothills of Eastern Andes Cordillera (Colombia, South America), has a large geological interest for being part of Llanos Basin, one of the most productive petroleum basins in that country. However, even previous theoretical geological analogical models shown a petroleum potential, the results of two wildcat wells (Coporo-1 and Palomas-1) were dry or unprofitable. Based on the contrasting result, this study would like to determinate why Medina Synclinory does not have a productive petroleum lead, under the hypothesis of the effect of post-trapping unburied faulting could affect the geometry of the potential petroleum trap; taking into account the Medina Synclinory's edges, Guaicaramo Fault and Tesalia-Servita Faulting System present reactivation in the Holocene. To understand the problem, this study observes the Quaternary deposits' behaviour, their deformation and folding structures with the aim to clarify their Neotectonics dynamics.

The methodology of this project includes: Regional and local previous geological references, a database with the collected information that includes the digital elevation model, preceding geological maps, STRM images, planimetric and altimetric information, data of dips of the layers, as well as seismic lines. The information was uploaded to Leapfrog Geo software to facilitate the 3D geological models and the consequent analysis. The information was classified, which determined two tools to be used for the generation of a three-dimensional model: First, A morphotectonic analysis of the Quaternary deposits based on the geometry and the relay faulting effect in their deposition, and second, Seismic lines interpretation, by means of continuity seismic parameters such as frequency, amplitude and internal geometry of the reflectors.

The morphotectonic analysis showed three types of relay faults styles: Stepped Failures, Leap Inflection and Parallel Staging. These faults were cyclically modelled in the software until a model was obtained that was coherent with the thicknesses, the seismic interpretation and the surface data, slope changes, rises of terraces, as well as variation in drainage patterns; showed guidelines in the deformation of the Quaternary deposits. The seismic interpretation allows to describe and determine the behaviour of the growth strata, which seems to be conditioned to the formation of relay failures, however this displacement does not generate a great displacement in the sequences. Considering this, it was possible to differentiate three units which were denominated "Seismic Units", SA, SB and SC, with SC being the most recent. The integral three-dimensional model and generate continuous surfaces of the lines of relay failures on the surface of the morphotectonic analysis, of the trace of the faults interpreted in the seismic lines and the so-called "seismic Units".

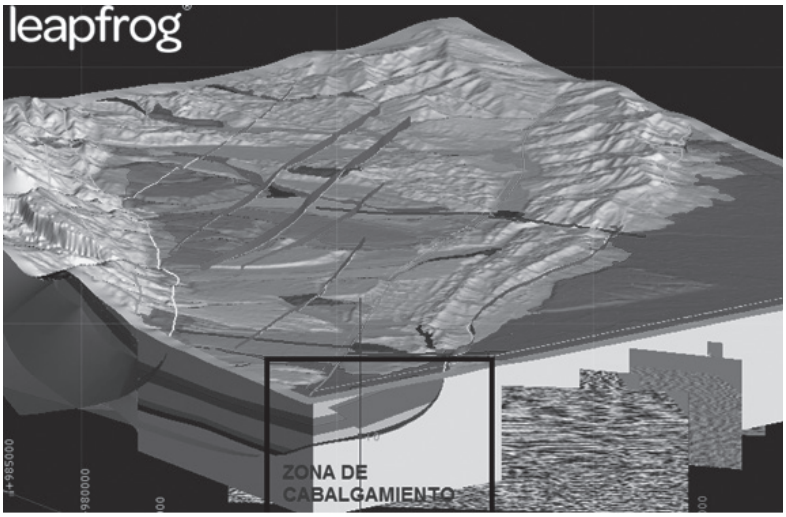

Figure 1. Three-dimensional model obtained from the interpretation of the seismic units and the morphotectonic analysis (Source: Silvana Morantes).

The study indicated that they are synthetic faults, generated by the subsidence, deposit and deformation of the structure. It is considered that the kinematics of the basin is being governed by a system of immature relay failures (See Fig. 1. CRIDER & PEACOOK, 2004) he is in the initial stage of his training. These only show evidence of affectation on the surface and are local in the subsoil. The geometry of the same is another indicator of what refers to this type of fault system, since it exhibits a slight curvature with lateral jumps. The generated three-dimensional model allowed to define the kinematics of the study area; in which a system of relay failures of normal type generated by tectono-sedimentary

events simultaneous to the subsidence of the structure is established. This occurs within a compressive regime of tectonic inversion, which affected the faults of Thessaly and Guaicaramo. In this new model, the failure of these faults can be considered as possible routes of local migration, making the hydrocarbons contained in the rocks of interest not reach the trap.

Keywords: *morphotectonic, relay faults, seismic interpretation, Medina Synclinory, Quaternary deposits*

References

CRIDER, J.G. & PEACOCK, D.C.P. (2004): Initiation of brittle faults in the upper crust: A review of field observations: Journal of Structural Geology, vol 26, 691-707.

Rudists and Chondrodonts from the Cenomanian of Istria (Croatia): Paleoenvironmental Implications

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The Adriatic Carbonate Platform (AdCP), which is one of the largest carbonate platforms during Mesosoic Era of the Perimediterranean region, also comprise a major part of the entire carbonate succession of the Croatian Karst (External or Outer) Dinarides, thick in some places more than 8000 m, and chronostratigraphically ranges from the Middle Permian (or even Late Carboniferous) to the Eocene (VLAHOVIĆ et al., 2005).

During the Late Cretaceous the AdCP was characterized generally by shallow-water peritidal depositional conditions, interrupted by two drowned platform events (MORO et al., 2002; VLAHOVIĆ et al., 2005). Rudists which throve in such paleoenvironments were elevators, sediment dwelling radiolitids. They are preserved mostly as in situ toppled congregations (ROSS & SKELTON, 1993) which ranges from the smallest bouquets towards cluster and finally the biggest thicket forms within laterally present biostromes representing floatstones to rudstones. Besides this most common appearance in the form of biostromes, in the Cenomanian of Istria at the Premantura locality, radiolitid-chondrodont congregations appear as mound and lensoidal forms.

Premantura succession is characterized by lateral and vertical exchange of floatstonesrudstones and packstones-grainstones. Along with complete shells and fragments of radiolitids and chondrodonts, other most common particles include benthic foraminifers, pellets and peloids.

Within the succession, radiolitid-chondrodont congregations occur through lateral exchange of lensoidal forms. Radiolitids and chondrodonts are within congregations in toppled or semi vertical growth position. Margins of the abovementioned forms are indicated with thin sheets of horizontally oriented chondrodont shells.

Lateral variability of radiolitid-chondrodont congregations indicate possible slight differences between bioproduction/bioerosion and sedimentation rate within the restricted accommodation space of the shallow water depositional paleoenvironment, close to the peritidal conditions. Relatively high bioproduction of radiolitids which laterally varies resulted with different growth morphologies of their congregations. Chondrodonts, which thrived together with radiolitids, indicated top of radiolitid-chondrodont congregations with thin sheets of their shells. Chondrodonts, as presumably less sediment dwellers then radiolitids, indicated decrease in bioproduction/bioerosion within the shallowest parts of subtidal.

Keywords: *rudists, chondrodonts, Istria, Premantura, shallow water carbonates*

References

MORO, A., SKELTON, P.W. & ĆOSOVIĆ, V. (2002): Palaeoenvironmental setting of rudists in the Upper Cretaceous (Turonian–Maastrichtian) Adriatic carbonate platform (Croatia), based on sequence stratigraphy. Cret. Res., 23, 489-508. doi:10.1006/cres.2002.1017

ROSS, D.J. & SKELTON, P.W. (1993): Rudist formations of the Cretaceous: a palaeoecological, sedimentological and stratigraphical review. Sediment. Rev., 1, 73-91.

VLAHOVIĆ, I., TIŠLJAR, J., VELIĆ, I. & MATIČEC, D. (2005): Evolution of the Adriatic Carbonate platform: palaeogeography, main eventsand depositional dynamics. Palaeogeography, Palaeoclimatology, Palaeoecology, 220, 333-360. doi:10.1016/j.palaeo.2005.01.001

Upper Cretaceous (Campanian) Transgressive Deposits from Mikulić Potok, Medvednica Mt., NE Croatia

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A Gosau-type transgressive succession, typical for the area of the Inner Dinarides, is exposed at Mikulić potok on the Medvednica Mt. (NE Croatia). The succession records a continental-to-marine transition consisting of basal conglomerates, shallow-marine sandstones and carbonates, followed by shales and pelagic Scaglia-type limestones (CRNJAKOVIĆ, 1979). The carbonate deposits with rudists form lens-like bodies, which are laterally enveloped by siliciclastics. They consist of a mixture of fine-grained siliciclastic detritus and carbonate grains with predominance of toppled rudist shells and their fragments.

The depositional environment is determined as subtidal with predominate siliciclastic sedimentation. Siliciclastic deposits generally do not contain any macrofossils. Exceptions can be found in the lower part of the succession with findings of inoceramid shells. Within siliciclastic-carbonate deposits rudists (hippuritids) are present, which are characteristic for relatively deeper subtidal with absence of shallowing-upward cyclicity, as well as relatively deeper and more open subtidal without influence of terrigenous input from emerged areas. The depositional setting of the investigated locality may be considered as a result of a relatively rapid sea-level rise with tectonic influence in the background. The result was a relatively short period of shallow-water sedimentation without repetition of peritidal conditions during a period of relatively rapid deepening. Transgression, which generally extended from north towards the southeast of the Inner Dinarides and covered different types of tectonically uplifted and eroded paleorelief, ranging from predominantly carbonate to siliciclastic deposition (MORO et al., 2016). Presumably, at this locality paleorelief was low and the transgressive succession started with clastic deposits. When subtidal paleonvironment became relatively more open and distant the transgressive succession characterize carbonate sedimentation with rudist communities.

Transgressive successions with similar vertical exchange of lithotypes have been studied at other localities (MORO et al., 2016) with Gosau-type transgressive successions, where first appearance of rudists is connected with establishment of carbonate sedimentation.

Keywords: *Gosau-type deposits, transgression, siliciclastics, carbonates, rudists*

References

CRNJAKOVIĆ, M. (1979): Sedimentacija transgresivnog senona na južnim padinama Medvednice. Geol. vjesnik, 32, 81-95.

MORO, A., HORVAT, A., TOMIĆ, V., SREMAC, J. & BERMANEC, V. (2016): Facies development and paleoecology of rudists and corals: an example of Campanian transgressive sediments from northern Croatia, northeastern Slovenia, and northwestern Bosnia. Facies, 62, 3, 1-25.

Carbonate Cobbles and Blocks from the Upper Cretaceous (Campanian) Debris Flow, Ozalj Area, NW Croatia

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The Dinaridic orogenetic belt comprise some of the thickest and most continuous Mesozoic sedimentary successions of the Perimediterranean region. Its deposits include a major part of the Cretaceous successions of Croatia, which are predominantly characterized by carbonates (Outer Dinarides) or mixed carbonates/siliciclastics (Inner Dinarides). While the area of the Outer Dinarides was characterized predominantly by shallow-marine deposition on the Adriatic Carbonate Platform, the area of the Inner Dinarides was characterized by basinal Gosau-type sedimentation consisting of deep-water carbonates (Scaglia), marls and gravity flow deposits which followed after relatively short periods of shallow-marine sedimentation. The Vivodina area in the Žumberak Mts. of NW Croatia comprises such deposits. Within the upper flysch type succession several types of gravity flow beds can be clearly differentiated based on their composition, grain-size and thickness. The most common are relatively thin (up to aprox. 10–20 cm) turbidite beds of carbonate or commonly mixed carbonate-siliciclastic composition. Interlayered with the thin sandstone turbidites are thick (often >1 m) carbonate turbidite beds consisting of coarse rudite carbonate lithoclasts at their bottom which upward grade into finer-grained, mostly skeletal detritus. Also within the succession occasional thick debris flow deposits occur characterized by chaotic structure composed of large carbonate clasts up to 1 m in size.

Near Ozalj, an outcrop of a thick carbonate bed composed of fossiliferous carbonate pebbles, cobbles and blocks was investigated in order to determine the origin and fossil content of the redeposited material.

Textural characteristics of the analyzed cobbles and blocks ranges from wackestones-packstones to grainstones. Macrofossils are represented by numerous small requieniids and some caprinids. Microfossil communities determined in thin sections are composed of *Dicyclina schlumbergeri* (MUNIER CHALMAS), *Palorbitolina lenticularis* (BLUMENBACH) and *Praeorbitolina cormyi* SCHROEDER as well as numerous miliolids. According to the macro- and microfossil communities the age of the carbonate clasts from this locality range from Aptian to Middle Turonian. In the wider area ZUPANIČ (1974) reported the presence of clasts ranging from Paleozoic to Upper Cretaceous in similar carbonate beds. The depositional paleoenvironment in which the above mentioned fossils thrived ranges from low-energy to relatively high-energy shallow subtidal. Biostratigraphically, requieniids are present throughout the Cretaceous, while caprinids range from the Aptian to the Cenomanian. Both clingers (requieniids) or mostly recumbents and rarely elevators (caprinids), thrive in more open paleoenvironments with relatively higher water energy, such as low-angle open shelf margin complexes, isolated build-ups, and steep margin complexes (for recumbent caprinids) (ROSS & SKELTON, 1993).

These debris flows consist of clasts which range from pebbles to blocks with fine-grained matrix between them. They were probably deposited on steep and short slopes along the southwestern margins of the Late Cretaceous foreland basin which flanked the emerged Adriatic Carbonate Platform.

Keywords: *debrite flows, Ozalj, carbonates, Upper Cretaceous*

References

ROSS, D.J. & SKELTON, P.W. (1993): Rudist formations of the Cretaceous: a palaeoecological, sedimentological and stratigraphical review. Sediment. Rev., 1, 73-91.

ZUPANIČ, J. (1974): Sedimentologija gornje krede sjevene Hrvatske. PhD thesis, University of Zagreb, Faculty of Science, 142 p.

Paleoenvironment of Gastropod Fauna from the Campanian Deposits of Gornje Orešje (Medvednica Mt., Croatia)

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Gosau-type basins, typical for Austroalpine and Inner Dinaric regions, were characterized by vertical succession of transgressive facies, with the development of fluvial-lacustrine to shallow-marine environments which characterizes deposition of conglomerates, coal-bearing marls, siliciclastics rich in corals, acteonellid and nereneid gastropods and rudist limestones, which finally passed into deep-water Scagila-type limestones or marls. At the Gornje Orešje locality on the Medvednica Mt. (NE Croatia) (MORO et al., 2016) from allochtonous, weathered part of of the Gosau-type facies outcrop rich in corals and rudists, 78 specimens of gastropod fauna were collected. Within collection 10 species and 15 genera were determined: *Trochactaeon* (*Neotrochactaeon*) *giganteus* (Sowerby, 1835), *Trochactaeon* (*Neotrochactaeon*) cf. *giganteus* (Sowerby, 1835), *Trochactaeon* (*Neotrochactaeon*) *goldfussi* (d`Orbigny, 1850), *Trochactaeon* (*Neotrochactaeon*) *sanctaecrucis* (Futterer, 1892), *Trochactaeon* (*Neotrochactaeon*) *obtusus* (Zekeli, 1852), *Trochactaeon* (*Neotrochactaeon*) *subglobosus* (Muenster, 1844), *Trochactaeon* (*Neotrochactaeon*) sp., *Trochactaeon* sp., *Parasimploptyxis buchi* (Muenster, 1829), *Parasimploptyxis* cf. *buchi* (Muenster, 1829), *Parasimploptyxis pailletteana* (d`Orbigny, 1842), *Parasimploptyxis* indet., *Pseudamaura bulbiformis* (Sowerby, 1831), *Pseudamaura* sp., *Trochus* sp., *Palaeocancellaria hoelleitenensis* Kollmann, 1976, *Echinobathra* sp., *Bicarinella* sp., *Astraea* sp., *Punctospira* sp., *Bathrotomaria* sp., *Cernina* sp., *Turritella fittoniana* (Muenster), *Natica* sp. and *Drepanocheilus* sp. From the collected material 11 specimens remained taxonomically indeterminated. According to the chronostratigraphic and biostratigraphic data from the fossil assemblage, Campanian age has been determined.

In comparison with other Gosau-type facies successions, the gastropod diversity is quite low concerning both genera and species. That could be due to the ecological preferences of determined genera within the investigated transgressive succession. Presumably above mentioned gastropod assemblage thrived as epifaunal vagrant benthos. They preferred mixed calcareous mud-siliciclastic substrate of shallow-marine moderately agitated subtidal platform environments. That kind of paleoenvironment was relatively narrow within the vertical succession of the typical transgressive Gosau-type facies, resulted with short period of gastropod's fauna abundant presence. Moreover, this characteristics of substrate could be one of ecological reasons for the rareness and absence of gastropods from typical subtidal paleoenvironments of the Adriatic Carbonate Platform (AdCP).

Keywords: *Gosau-type facies, transgression, gastropods, Medvednica Mt., Gornje Orešje*

References

MORO, A., HORVAT, A., TOMIĆ, V., SREMAC, J. & BERMANEC, V. (2016): Facies development and paleoecology of rudists and corals: an example of Campanian transgressive sediments from northern Croatia, northeastern Slovenia, and northwestern Bosnia. Facies, 62:19. DOI 10.1007/s10347-016-0471-y.

Upper Cenomanian–Lower Turonian Sequence Boundary on the Adriatic Carbonate Platform: An Example from the Korčula Island

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The Adriatic Carbonate Platform (AdCP) is one of the largest Mesozoic carbonate platforms of the Perimediterranean region. Its predominately shallow water deposits comprise a major part of the entire carbonate succession of the Croatian Karst (External or Outer) Dinarides, which could be very thick, and ranges in age from the Middle Permian (or even Upper Carboniferous) to the Eocene (VLAHOVIĆ et al., 2005).

During the Late Cretaceous, numerous sequences were deposited within shallow water depositional environments (HAQ, 2014). The Adriatic Carbonate Platform (AdCP) during the Late Cretaceous was characterized predominantly by shallow water sedimentation with few events marking beginning of sequences: two drownings of the platform (Cenomanian/Turonian and Santonian) and Campanian emergence (GUŠIĆ & JELASKA, 1990; MORO et al., 2002; VLAHOVIĆ et al., 2005). Besides typical shallow water environments with predominantly low-energy, protected paleoenvironments, mud-supported varieties of carbonates with elevator rudists, during Late Cenomanian more open paleoenvironment of relatively higher water energy also occur, characterized by predominantly grain-supported carbonates with recumbent ichthyosarcolitid and caprinid rudists. Their demise coincides with the Cenomanian-Turonian boundary (ROSS & SKELTON, 1993).

At the Korčula Island succession of Cenomanian deposits is characterized by alternation of shallow-water peritidal laminated and non-laminated carbonates with thin layers of grainy carbonate variates and absence of typical drowned platform deposits. Although beginning of the Cenomanian/Turonian drowning coincides with OAE2 event (VLAHOVIĆ et al., 2005) characterized on global scale with the highest sea-level rise, that period was also characterized by very common relatively short-lasting third-order sequences, five of them within 3.7 Ma (HAQ, 2014). Moreover, during the Cenomanian the beginning of the AdCP demise was characterized by the occurrence of emerged areas in the NW part of the AdCP. Although above mentioned relatively dense presence of sequences around Cenomainan/Turonian boundary could be indicated byflodding of emerged areas more open, high energy paleoenvironments with recumbent rudists as well as drowned platform event with pelagic sedimentation as indication of the new sequence beginning, most probably influence of the local tectonics were the main controlling factor in their presence or absence in the southern part of the AdCP.

Keywords: Upper Cretaceous, tectonics, Korčula Island, shallow-water carbonates

References

GUŠIĆ, I. & JELASKA, V. (1990): Stratigrafija gornjokrednih naslaga otoka Brača u okviru geodinamske evolucije Jadranske karbonatne platforme (Upper Cretaceous stratigraphy of the Island of Brač within the geodynamic evolution of the Adriatic Carbonate Platform). JAZU and Inst. za geol. istraž., Zagreb, 160 p.

HAQ, B.U. (2014): Cretaceous eustasy revisited. Glob. Planet. Change, 113, 44-58. doi:10.1016/j.gloplacha.2013.12.007

MORO, A., SKELTON, P.W. & ĆOSOVIĆ, V. (2002): Palaeoenvironmental setting of rudists in the Upper Cretaceous (Turonian–Maastrichtian) Adriatic carbonate platform (Croatia), based on sequence stratigraphy. Cret. Res., 23, 489-508. doi:10.1006/cres.2002.1017

ROSS, D.J. & SKELTON, P.W. (1993): Rudist formations of the Cretaceous: a palaeoecological, sedimentological and stratigraphical review. Sedimentol. Rev., 1, 73-91.

VLAHOVIĆ, I., TIŠLJAR, J., VELIĆ, I. & MATIČEC, D. (2005): Evolution of the Adriatic Carbonate platform: palaeogeography, main eventsand depositional dynamics. Palaeogeogr., Palaeoclim., Palaeoecol., 220, 333-360. doi:10.1016/j.palaeo.2005.01.001

Holocene Transgression of the Northern Adriatic Alluvial Plain: A Correlation of the Sedimentary and Acoustic Facies in the Gulf of Trieste

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The post-glacial sea-level rise greatly affected shallow continental shelves. One such example is the northern Adriatic, where the vast alluvial plain was transgressed approximately 10 ky ago and transformed into a shallow marine environment. We studied the southern part of the Gulf of Trieste where the alluvial sedimentary record is exceptionally well-preserved and buried beneath a few meters thick layer of Holocene-recent marine sediments. Our aim was to correlate the shallow high-resolution geophysical record to the marine-continental succession of the seabed sediments and to provide an estimate of the sediment ages. Acoustic profiles, from which we determined several acoustic facies, were acquired with the Innomar SES-2000 compact sub-bottom profiler. Sediment samples corresponding to these acoustic facies were sampled with the Uwitec gravity corer, described and dated with AMS radiocarbon dating.

The oldest sampled unit is Late Glacial (approx. 30 ky cal BP) fluvio-eolian sandy mud which can be recognized in the geophysical record by low-amplitude chaotic geometries. The sandy mud is covered by graded deposits (sandy mud and sandy clay grading into clay) which are expressed as an acoustic facies of high-amplitude and high-frequency sub-horizontal reflection geometries. Ostracod shells from these two units are of the same age. The graded deposits are followed by mud and clay deposited between the Last Glacial Maximum and the Early Holocene. These fine-grained deposits can be recognized on the geophysical profiles as an acoustically transparent facies containing individual sub-horizontal or slightly undulating discontinuous low- to middle-amplitude reflections. The fine-grained deposits are covered by Early Holocene bioclastic sandy mud containing brackish mollusk assemblages. In the geophysical record this unit is characterized by an acoustic facies containing onlapping and concordant middle- to low- amplitude reflection geometries. Finally, the sedimentary succession is topped by bioclastic sandy mud with shallow marine shell assemblages which is expressed as a transparent acoustic facies.

Our work provides an insight into the evolution of the Late Pleistocene alluvial plain during the Late Pleistocene-Holocene transition in the study area. Late glacial fluvio-aeolian sediments were reworked and redeposited by floods in the form of graded deposits. After the Last Glacial Maximum the alluvial plain favored fine-grained sediment deposition with prevailing overbank deposits. The advancing Holocene transgression reached our study area in the Early Holocene without significant erosion of the Late Pleistocene alluvial sequences. However, the transgression is indicated in the sedimentary record by thin transgressive muds. With the advancing sea-level rise, the relatively thin transgressive deposits were covered by thick (5 meters on average) shallow marine sediments in the southern part of the Gulf of Trieste. In addition to the evolutionary model, our study provides the first correlation of sedimentary and acoustic facies of a Late Quaternary succession on a well-preserved mid-to-low latitude alluvial plain transgressed during the Holocene.

Keywords: *Holocene transgression, sub-bottom sonar, alluvial plain, northern Adriatic, Gulf of Trieste*

Multi-Disciplinary Study of Post LGM Sedimentary History of Glacial Planica Valley (Julian Alps, NW Slovenia)

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The Planica Valley (Julian Alps, NW Slovenia) is a glacial valley bounded by steep slopes of Triassic mainly carbonate rocks, and represents an ideal place for studies of post-glacial Quaternary sedimentation. The valley is currently being filled with Holocene sediments deposited by rock falls, debris flows and fluvial flows. In addition, glacial deposits are still well preserved. The deposited sediments are forming complex and intercalated sedimentary bodies, each with a complex history of sedimentation and erosion.

Aims of our research are (i) to identify different slope sedimentation processes based on their sedimentological and geomorphological characteristics, (ii) to build more than a century long chronology of slope mass movement activity based on tree-ring data, (iii) to detect surface changes of annually transported sediment using georeferenced UAV images and (iv) to link different sedimentary processes to bedrock geology and potential triggering events. Herein we present an overview of preliminary results and present the future research proposals. In the ongoing research we identified four different types of Holocene sedimentary bodies; a) scree deposits, b) alluvial fans, c) a debris flow deposit and d) fluvial deposits. Sedimentation of scree deposits is driven mainly by occasional rock-falls, while sedimentation on alluvial fans is water driven. Alluvial fans in the Planica Valley are the most active and complex sedimentary bodies, with sediment transport mechanisms varying from bed load transport to debris floods. Bed load transport occurs occasionally during regular annual precipitation events while debris floods occur during high autumnal precipitation events and are most frequent transport and depositional process. Debris flood deposits are forming relatively thin, wide sheets of poorly sorted, clast-supported open framework sand to gravel debris which lacks fine grained component and buries trees but often cause little to no mechanical damage. Using tree-ring analysis of partially buried trees growing on the surface of alluvial fans affected by debris floods we have created more than a century long spatio-temporal reconstruction of these events. Dated events were later linked with precipitation records which allowed us to pinpoint the initiation of debris flooding with a daily precision. Correlation between return period of individual triggering meteorological event and the number of affected trees enabled us to determine the magnitudes of previous events. The debris flow deposit represents infrequent and sudden transportation event, which was triggered by a combination of above average precipitation event in November 2000 and bedrock geology, namely the Triassic Tor formation. Debris flow deposit is formed of typical debrite composed of angular, very poorly sorted sediment whose fraction varies from clay size grains to blocks of a few cubic metres. In addition to Holocene sedimentary bodies, we have identified Pleistocene till which forms large moraine bodies as well as remains of lacustrine sediments deposited during glacial retreat. To accurately place individual sedimentary bodies in the research area 3D surface models were built from images obtained by UAV. The obtained UAV data will also serve for constructing high resolution digital models for future research of active slope mass movements. The presented research is the first multi-disciplinary study of complex post glacial sedimentation in alpine environment in Slovenia.

Keywords: *Quaternary Geology, Holocene, sedimentary bodies, dendrogeomorphology, Julian Alps*

Reservoir Quality Description Based on Porosity-Thickness Maps, Pannonian Reservoir, Sava Depression

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Analysed area is located in the NW part of the Sava Depression. During the Pannonian the whole area of the CPBS (Croatian part of Pannonian Basin system) was covered with deep lake called the Pannonian Lake. Sedimentation took place through turbidite currents, which had NW-SE direction (RÖGL, 1996, 1998; VRBANAC, 1996). Deposited material originated from the Eastern Alps and it had been several time redeposited before finally entered the Sava Depression. Long material transport caused sedimentation of medium to fine grained sand (SAFTIĆ et al., 2003; VRBANAC et al., 2010). Sand was deposited during the activity of turbidite currents and among those events, mud and clay, as typical deep water material filled the depression. Due to that fact, interbeding of sandstones and marls in analysed reservoirs is present.

The analysed hydrocarbon field is represented with asymmetrical brachyanticline with a bit longer axis of NW-SE strike. Oil bearing reservoirs are fine to medium grained quartz-mica sandstone with frequent alternation to compact, dense basinal marls. Sandstone and marl layers are not developed continuously through the field.

Since 2014, Pannonian reservoirs of the analysed field have been scope of the EOR (enhanced oil recovery) project. For that purpose, statical and dynamical model in Petrel™ software was created. Different deterministical and stochastical geostatistical methods have been tested. Best results of petrophysical modelling were obtained by deterministic Ordinary Kriging method (NOVAK ZELENIKA et al., 2017).

This study is intended for optimization of the CO_2 injection project. Main idea is that injected CO_2 wouldn't migrate through all parts of the reservoir equally, i.e. higher fluid flow is expected to be in the parts of the reservoir with better reservoir properties. For that purpose, visibility of depositional channels on maps is necessary. According to VRBANAC et al. (2010), there are four different lithofacies association in the analysed reservoirs:

1. turbidite channel fill facies association (blocky shape of the SP curve),
2. turbidite overbank-levee facies association (fining or coarsing upwards shape of the SP curve),
3. lateral or distal turbidite facies association (egg shape of the SP curve),
4. the facies of massive or basinal marls.

As it was explained in NOVAK ZELENIKA et al. (2018), porosity-thickness maps are excellent tool for reservoir quality description and for defining of depositional channels location. Such maps were created for three largest analysed reservoirs. Obtained porosity-thickness maps have role in fluid flow prediction and production optimization.

Keywords: *Porosity-thickness maps, turbidite channels, Pannonian reservoirs, EOR, Sava Depression*

References

NOVAK ZELENIKA, K., NOVAK MAVAR, K. & BRNADA, S. (2018): Comparison of the Sweetness Seismic Attribute and Porosity-Thickness maps, Sava Depression, Croatia. Geosciences, 8, 426, 14 p.

NOVAK ZELENIKA, K., VIDAČEK, R., ILIJAŠ, T. & PAVIĆ, P. (2017): Application of deterministic and stochastic geostatistical methods in petrophysical modelling – a case study of Upper Pannonian reservoir in Sava Depression. Geologia Croatica, 70/2, 105-114.

RÖGL, F. (1996): Stratigraphic Correlation of the Paratethys Oligocene and Miocene. Mitteilungen Ges. Geol. Bergbaustudenten Österreich, 41, 65-73.

RÖGL, F. (1998): Palaeographic Consideration for Mediterranean and Paratethys Seaways (Oligocene to Miocene). Ann. Naturhist. Mus. Wien, 99A, 279-310.

SAFTIĆ, B., VELIĆ, J., SZTANO, O., JUHAS, G. & IVKOVIĆ, Ž. (2003): Tertiary subsurface facies, source rocks and hydrocarbon reservoirs in the SW part of the Pannonian Basin (northern Croatia and south-western Hungary). Geologia Croatica, 56, 1, 101-122.

VRBANAC, B. (1996): Paleostrukturne i sedimentološke analize gornjopanonskih naslaga formacije Ivanić-Grad u Savskoj depresiji [Palaeostructural and sedimentological analysis of the Upper Pannonian sediments of the Ivanić-Grad formation in Sava Depression – in Croatian, with an English Abstract]. Unpubl. PhD Thesis, Faculty of Science, University of Zagreb, 121 p.

VRBANAC, B., VELIĆ, J. & MALVIĆ, T. (2010): Sedimentation of deep-water turbidites in main and marginal basins in the SW part of the Pannonian Basin. Geologica Carpathica, 61, 1, 55-69.

The Provenance of Lower Miocene Sandstones from Mt. Kalnik

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Mt. Kalnik is an inselberg structure in Northern Croatia that lies in the intersection zone between SE Alps, Internal Dinarides and SW Pannonian basin. With E-W striking ridge Mt. Kalnik is characterized by average altitude between 300 to 500 m and highest elevation of 642 m a.s.l. The southern margin of Mt. Kalnik is delineated by the combined reverse (e.g. Selanec-Poganac fault) and tectonically reactivated normal faults (e.g. Kalnik and Salamunovec-V. Botinovac faults), while on the northern side Mt. Kalnik it bounded by the reverse Drenovec fault. The Ljubelj fault divides Mt. Kalnik into two parts, Peca in the southern and Ljubelj in the northern part.

During its geological history Mt. Kalnik was affected by the tectonic phases of the Hercynian orogeny and Alpine orogeny with intense thrusting and faulting of Jurassic, Cretaceous and Paleogene complexes (ŠIMUNIĆ & HEĆIMOVIĆ, 1979; ŠIMUNIĆ et al., 1982), however only the Neogene-Quaternary tectonic evolution of the SW Pannonian basin is well expressed in the field. The tectonic uplift of Mt. Kalnik began at the end of the Miocene, however it climaxed during the Pliocene and Quaternary due to N-S directed shortening when Mt. Kalnik experienced differential uplift of several hundred meters (HEĆIMOVIĆ, 1995), which exposed pre-Neogene and Neogene tectonostratigraphic units surrounded by Plio-Quaternary sediments.

In this study our aim was to constrain the source area of the Lower Miocene sandstones from Mt. Kalnik which were deposited in fluvial and lacustrine environments during the Ottnangian and Karpatian (PAVELIĆ et al., 2001). For this purpose quantitative heavy mineral analysis was conducted on eleven samples from different sampling localities. Six localities (samples K25, K28, K35b, K16F, K23b, K26) are situated in the central and southern part of Mt. Kalnik, and five (samples K37, K41b, K38, K36, K30b) in the western part near Novi Marof and Breznički Hum. The samples were crushed and sieved, treated with 5% acetic acid, and grains within the 63 to 125 μm fraction were cleaned from adhering clays. Sodium polytungstate was used for mineral separation. About 250-300 translucent grains, excluding micas and Fe-oxides, were optically determined by ribbon counting in each sample.

Results show that analyzed samples are dominated by garnet that makes up approximately 25-70% of all translucent heavy minerals, along with rutile, tourmaline, zircon, staurolite and kyanite (Fig. 1). The content of minerals from epidote/zoisite group is rather low. The

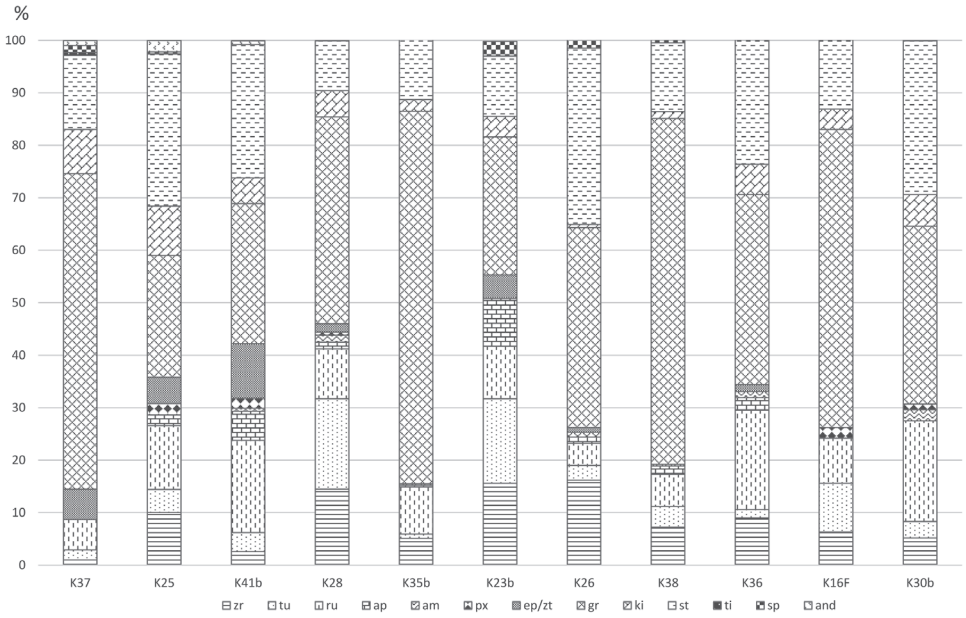

Figure 1. Heavy mineral composition of Lower Miocene sandstones from Mt. Kalnik.

zircon-tourmaline-rutile (ZTR) index is 20-25% on average. The presence of garnet, staurolite and kyanite could indicate a metamorphic origin of initial source material. This furthermore implies that the most probably source of the material were the Alps, since in the Lower Miocene there were no prominent mountains in the local area. The apatite-tourmaline (ATi) index is very low in most of the samples, which can be seen as source information, but more likely is a result of dissolution of unstable apatite by acidic weathering. Weathering could also be the reason for the low content of amphiboles and pyroxenes.

Due to ambiguity of the results and the fact that the composition of heavy mineral assemblages in sandstones may be influenced by many processes during transport, deposition and diagenesis, geochemical analysis of detrital garnet and rutile grains on several representative samples provide additional information on the provenance, because varietal characteristics of individual mineral species are usually inherited directly from the source area.

Keywords: *Miocene, Mt. Kalnik, provenance, heavy minerals, geochemistry*

References

HEĆIMOVIĆ, I. (1995): Tektonski odnosi šireg područja Kalnika. Doktorska disertacija. Rudarsko-geološko-naftni fakultet, Sveučilište u Zagrebu, 30-131.

PAVELIĆ, D., AVANIĆ, R., BAKRAČ, K. & VRSALJKO, D. (2001): Early Miocene braided river and lacustrine sedimentation in the Kalnik mountain area (Pannonian Basin System, NW Croatia). Geologica Carpathica, Vol 52, 375-386.

ŠIMUNIĆ, A. & HEĆIMOVIĆ, I. (1979): Tektonski odnosi sjeverozapadne Hrvatske (Ivanščica, Kalnik i Ravna gora). Zbornik radova Znan. savjeta za naftu Jugosl. akad. znan. umjet., Sekcija za primjenu geologije, geofizike i geokemije, IV god. znan. skup, 188-198, Zagreb.

ŠIMUNIĆ, A., NAJDENOVSKI, J. & ŠIMUNIĆ, A. (1982): Geološki odnosi sjeverozapadnog dijela Dravske depresije i istočnih obronaka Kalničkog gorja. Zbor. rad. Jug. geol. Kongresa, Budva, 1, 107-122.

The Provenance of Drava Alluvial Terrace Sediments in the Area of Bilogora

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Bilogora is a Plio-Quaternary transpressional morphostructure of Dinaridic orientation situated in the southwestern part of the Pannonian Basin. Its tectonic origin is associated with Neogene-Quaternary evolution of the Drava Depression, i.e. Pliocene-Quaternary tectonic inversion and structural reactivation of Neogene faulted structures. This hilly terrain occupies Drava Depression and Bjelovar Subdepression being composed of thick Neogene and Quaternary sediments succession (KRANJEC et al., 1971; SAFTIĆ et al., 2003).

Sediment deposition during the Quaternary was associated with the hydrodynamic system of paleo-Drava River. The Drava River created four alluvial terraces through Quaternary, two of them exposing Pleistocene and two Holocene clastic succession (ŠIMUNIĆ et al., 1990). The oldest of the four Drava terraces exposed in the Bilogora area consists of cyclic coarse grained gravel succession (sub to well rounded pebbles) altering with subordinate sand and silt layers that are covered by Late Glacial/Late Pleistocene aeolian fine grained sediments like loess ad loess-like sediments. The total thickness of Pleistocene alluvial sediments is up to 80 m (ŠIMUNIĆ et al., 1990).

In this study principal research objectives were to constrain the source area of the Pleistocene alluvial sediments in the area of Bilogora. The studied alluvial sediments were previously dated by luminescence dating technique which imply to a Middle Pleistocene age (WACHA et al., 2018). Quantitative heavy mineral analysis was conducted on a 25 samples from eight different localities along the Bilogora. In the northwestern part of Bilogora ten samples were collected, four samples were collected from Mučna Reka, four samples from Novigrad Podravski and two from Se-

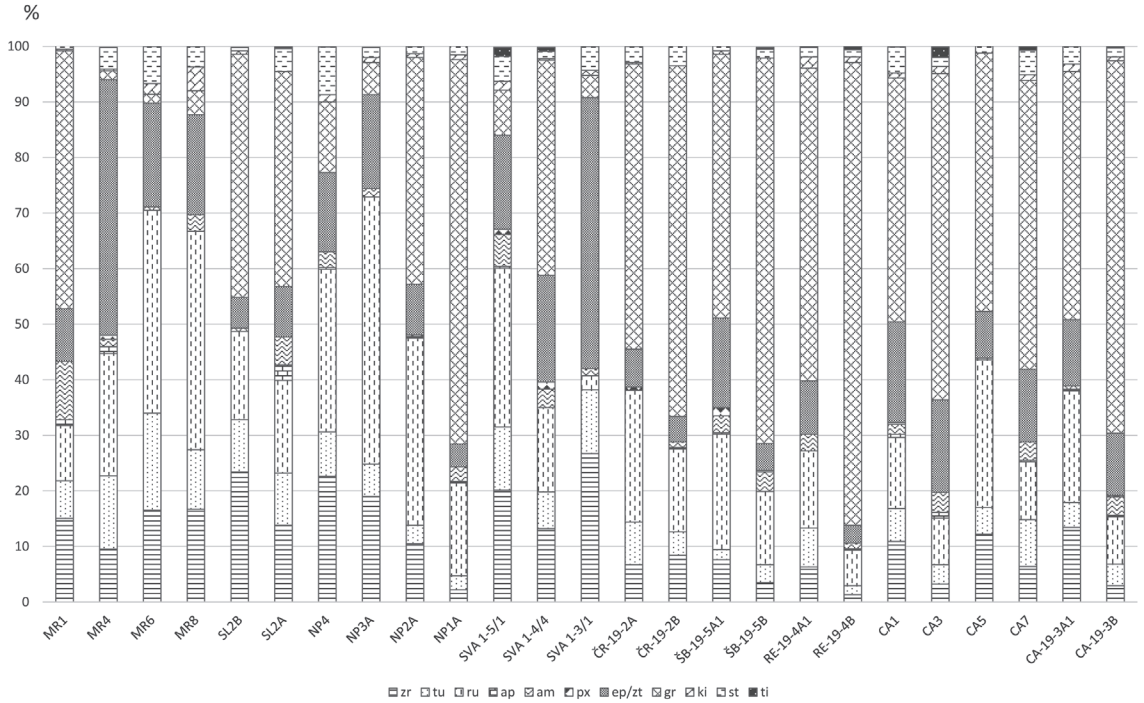

Figure 1. Heavy mineral composition of sand and loess from the area of Bilogora (MR1, CA1, SL2B – loess).

linec. Three samples were collected in Sveta Ana and two from Črešnjevica, both located in the central part of the Bilogora. Final ten samples, six from Cabuna, two from Špišić Bukovica and two from Rezovac were collected in the southeastern part of the study area.

Results show that samples from the southeastern part are dominated by garnet that makes approximately up to 50% of all translucent heavy minerals, along with epidote/zoisite, rutile and tourmaline (Fig.1). This suggests a dominant Alpine source of the generated sediment (MUTIĆ, 1975). The transported material probably had arrived directly from NW and was deposited by the paleo-Drava River, or it may have been originated from recycled uplifted Neogene strata. The sand from the central part of the Bilogora Mt. contains mostly of epidote/zoisite, followed by garnets, amphiboles and rutile. The proportion of garnet appears to decrease towards the northwest. At Mučna Reka site, the samples are almost entirely depleted of garnet what is quite unusual as Holocene sands of the Drava River and most of the loess and older Neogene sediments in the area are rich in garnet of Alpine provenance. This could indicate a local origin of the detritus, possibly from pre-Neogene basement rocks being exhumed in the nearby Kalnik and Ivanščica mountainous area to the west, or/and Slavonian mountains to the southeast.

On some of the studied localities conspicuous pebbles of light coloured tuffs with biotite and other volcanic lithologies have been found. Similar volcanic rocks were deposited on the Mt. Kalnik during the Lower Miocene. U(Th)/He dating on apatite grains from the tuffs has shown an average age of 19 Ma. Since the collected pebbles were very soft and easy to disintegrate, it is highly improbable that they were transported over long distances. This possibly pinpoint to the local origin of at least part of the detritus in the Bilogora area.

Due to ambiguity of the results and the fact that the composition of heavy mineral assemblages in sands may be influenced by many processes during transport, deposition and diagenesis, geochemical analysis of detrital garnet and rutile grains and U/Pb dating on rutiles on several representative samples provide additional information on the provenance, because varietal characteristics of individual mineral species are usually inherited directly from the source area.

Keywords: Bilogora, aggradational alluvial terraces, Pleistocene, provenance, heavy minerals

References

KRANJEC, V., PRELOGOVIĆ, E., HERNITZ, Z. & BLAŠKOVIĆ, I. (1971): O litofacijelnim odnosima mlađih neogenskih i kvartarnih sedimenata u širem području Bilogore (Sjeverna Hrvatska). Geološki vjesnik, 24, 47-55.

MUTIĆ, R. (1975): Pijesak rijeke Drave u naslagama bušotine B-12 nedaleko Podravske Slatine. Geološki vjesnik, 28, 243-268.

SAFTIĆ, B., VELIĆ, J., SZTANO, O., JUHASZ, G. & IVKOVIĆ, Z. (2003): Terciary subsurface facies, source rocks and hydrocarbon reservoirs in the SW part of the Pannonian Basin (Northern Croatia and South-Western Hungary). Geologia Croatica, Vol 56/1, 101-122.

ŠIMUNIĆ, A., HEĆIMOVIĆ, I. & AVANIĆ, R. (1990): Basic geological map of the Republic of Croatia., M 1:100 000, Sheet Koprivnica (L33-70). Croatian Geological Survey, Zagreb, 2013.

WACHA, L., MATOŠ, B., KUNZ, A., LUŽAR OBERITER, B., TOMLJENOVIĆ, B. & BANAK, A. (2018): First post-IR IRSL dating results of Quaternary deposits from Bilogora (NE Croatia): Implications for the Pleistocene relative uplift and incision rates in the area. Quaternary International, 494, 193-210.

Mineralogical and Geochemical Characteristics of the Middle Miocene Tuffs from Bukova Glava Locality, Krndija Mountain (NE Croatia)

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Bukova Glava locality, in the vicinity of the town Našice, is a southern section of a large quarry owned by "Našicecement d.d." company. The section consists of approximately 100 m thick deposits of middle Miocene age. The deposits are grouped into three main lithofacies: algal limestones, biocalcrudites and marls (PAVELIĆ et al., 2003) along with lithofacies of pyroclastites (KOVAČIĆ et al., 2015).

Four layers of altered tuffs few centimetres in thickness were found on the Bukova Glava section of which three have been sampled: first, third and fourth in the sequence. Although all three samples are predominantly composed (~98%) of particles smaller than 63 μm, determination of volcanic origin was carried out by modal analysis of the 63–125 μm fraction. Mineral composition of light and heavy fractions was determined by optical microscopy and XRD analysis. Tuffs of the first and fourth layer in sequence are characterized by similar mineral association of light and heavy mineral fraction with different shares. Devitrified volcanic glass particles are dominant in light mineral fraction with less common quartz, mica, plagioclase, tridymite, cristobalite and sanidine, while heavy mineral fraction consists of garnet, zircon, apatite and phyllosilicate minerals like muscovite, biotite and chlorite. Tuffs of the third layer in sequence significantly differs from the other two analysed tuffs. About 90% of the light mineral fraction consists of gypsum with subordinate quartz, cristobalite, tridymite and mica, while the mineral phases that prevail in the heavy mineral fraction are opaque minerals and jarosite with weakly represented zircon, garnet, apatite, tourmaline, clinozoisite, muscovite, biotite, chlorite and barite. XRD analysis confirmed that the opaque minerals are mainly represented by ilmenite, assumed to have terrigenous origin. Also, presence of gypsum in the light mineral fraction may indicate the primary presence of sulfides whose oxidation could lead to the formation of secondary sulfate minerals (ZIMBELMAN et al., 2005).

Whole rock analysis of tuffs was obtained by inductively coupled plasma atomic emission spectroscopy (ICP-AES) and mass spectroscopy (ICP-MS) in Bureau Veritas Commodities Canada Ltd. The main characteristics of analysed tuffs are significant values of LOI (23.30–25.20 wt.%) and similar SiO_2 (47.91–50.21 wt.%) content. Discrimination diagram based on the ratio of immobile elements Zr/Ti vs. Nb/Y (PEARCE, 1996) was used for general classification of tuffs due to highly altered layers of tuffs, so other discrimination diagrams based on mobile elements could possibly give incorrect data. According to the Zr/Ti vs. Nb/Y diagram, tuffs of the first and fourth layers correspond to the field of neutral series, i.e. tephriphonolite, and tuffs of the third layer plotted in the field of alkali basalts. In our opinion, presence of terrigenous ilmenite could reduce the value of Zr/Ti ratio, and thereby shift the result to the basic part of discrimination diagram. Discrimination diagram for granites based on immobile elements Y, Nb, Ta i Yb (PEARCE et al., 1984) was used to determine the geotectonic setting of tuffs formation. The diagram showed that the source for all three tuffs was the active continental margin. At that time, in middle Miocene, the closest active continental margin was in the middle part of Eastern Carpathians and presents the most likely source of volcanism (KONEČNÝ et al., 2002).

This research confirmed volcanic origin and neutral geochemical character of altered tuffs. The potential volcanic source is the active continental margin located in the middle part of Eastern Carpathian. The radiometric method should be the focus of future research to determine the absolute age of tuffs.

Keywords: *Bukova Glava, Krndija Mt., NE Croatia, tuffs, Middle Miocene, tephriphonolite*

References

KONEČNÝ, V., KOVÁČ, M., LEXA, J. & ŠEFARA, J. (2002): Neogene evolution of the Carpatho-Pannonian region: an interplay of subduction and back-arc diapiric uprise in the mantle. EGU Stephan Mueller Special Publication Series 1, 105-123.

KOVAČIĆ, M., ĆORIĆ, S., MARKOVIĆ, F., PEZELJ, Đ., VRSALJKO, D., BAKRAČ, K., HAJEK-TADESSE, V., BOŠNJAK MAKOVEC, M., RITOSA, A. & BORTEK, Ž. (2015): Karbonatno-klastični sedimenti srednjeg i gornjeg miocena (kamenolom tvornice cementa kod Našica). 5. hrvatski geološki kongres – Vodič ekskurzija. Hrvatski geološki institut, Zagreb, 82-85.

References

PAVELIĆ, D., AVANIĆ, R., KOVAČIĆ, M., VRSALJKO, D. & MIKNIĆ, M. (2003): An outline of the Evolution of the Croatian Part of the Pannonian Basin System. In: VLAHOVIĆ, I. & TIŠLJAR, J. (eds.): Evolution of Depositional Environments from the Paleozoic to the Quaternary in the Karst Dinarides and the Pannonian Basin. 22nd IAS Meeting of Sedimentology. Opatija, Field Trip Guidebook, Zagreb, 155-161.

PEARCE, J.A. (1996): A user's guide to basalt discrimination diagrams. In: WYMANN, D.A. (ed.): Trace element geochemistry of Volcanic Rocks: Applications for Massive Sulphide Exploration. Geological Association of Canada, Short Course Notes 12, 79-113.

PEARCE, J.A., HARRIS, N.B.W. & TINDLE, A.G. (1984): Trace element discrimination diagrams for the tectonic interpretation of granitic rocks. Journal of Petrology, 25, 956-983.

ZIMBELMAN, D.R., RYE, R.O. & BREIT, G.N. (2005): Origin of secondary sulfate minerals on active andesitic stratovolcanoes. Chemical Geology 2015, 37-60.

On Granite Emplacement Mechanisms at Moslavačka Gora (Croatia): The Role of the Xenolith Studies

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Xenoliths are foreign fragments of sedimentary, metamorphic and igneous rocks, mainly angular in shape with sharp contacts toward the surrounding igneous host rock. They are predominantly found near pluton margins, especially in their apical parts. Fragmentation of country rock and entrainment of xenoliths by the intruding magma is directly related to the magma emplacement processes in the upper crust. One of the emplacement mechanisms, called stoping, involves fracturing of the wall rocks and floating or sinking of the detached blocks. The main field evidence for the stoping mechanism include: 1) sharp, discordant contacts between plutons and wall rocks, 2) a lack of pluton-related ductile deformation of wall rocks, 3) xenoliths in plutons, 4) mixed population of xenoliths in plutons, 5) evidence for rotation of xenoliths, and 6) geochemical evidence for magma contamination (GLAZNER & BARTELY, 2006).

In the case of Moslavačka Gora (MG), granitoid rocks comprising a central part of the crystalline are associated with various types of medium- to high-grade metamorphic rocks that are also present throughout the pluton in form of xenoliths of different sizes (KOROLIJA & CRNKO, 1985; PAMIĆ, 1990). One of the best xenolith exposures can be found in an abandoned quarry of Pleterac. At the studied locality, a leucocratic host rock, typical MG two-mica granite, hosts various sizes of metamafic xenoliths (amphibolites). They are characterized by angular shapes and mainly show sharp contacts toward the granite. Leucogranite dykes of variable width (cm to m) cross-cut the two-mica granite and sometimes xenoliths can also be observed throughout the quarry. Microstructurally, the studied amphibolite samples collected from xenoliths are divided into three groups. All of them are characterized by the well-developed foliation but variable mineral proportions resulting in more massive (Hbl>>Pl>Di), net-structured (Pl=Hbl>Di) or distinct stromatic appearance (Hbl>Di>Pl). Stromatic amphibolites contain significant amount of diopside following the preferred orientation of amphibole in the sample. Furthermore, three types of leucocratic rocks were sampled in the quarry, two of them corresponding to the already mentioned two-mica granites and leucogranites, while the third rock type was classified as trondhjemite. Clear chemical distinction can be made between the trondhjemite and the two granite types based on the REE trends, accompanied by high SiO_2 (85.45 wt.%), low K_2O (1.27 wt.%) and a pronounced positive europium anomaly (Eu/Eu*=4.05), high La_N/Yb_N (5.06) and low Yb_N (1.15) (Fig. 1a). The occurrence of trondhjemite and diopside in the metamafic xenoliths, together with the coarse equigranular nature of the leucocratic segregations and the development of accompanying Hbl-rich melanocratic envelopes, indicates a process of dehydration melting of amphibole through the reaction Hbl + Pl + Qtz = Di ± Ttn ± Grt + trondhjemite melt (HARTEL & PATTISON, 1996). Field evidence points to segregation of the produced trondhjemitic melt and formation of lenticular to vein-like leucosomes that are predominantly concordant with the main foliation in the xenoliths, whereas effects of melt migration can be observed only locally. Additionally, our observations, especially the uniformity of textural features throughout the blocks on the macro- and microscale, imply that the anatectic reaction mentioned above took place before the entrainment of xenoliths by the intruding magma, relating it to an earlier metamorphic episode of the MG crystalline evolution.

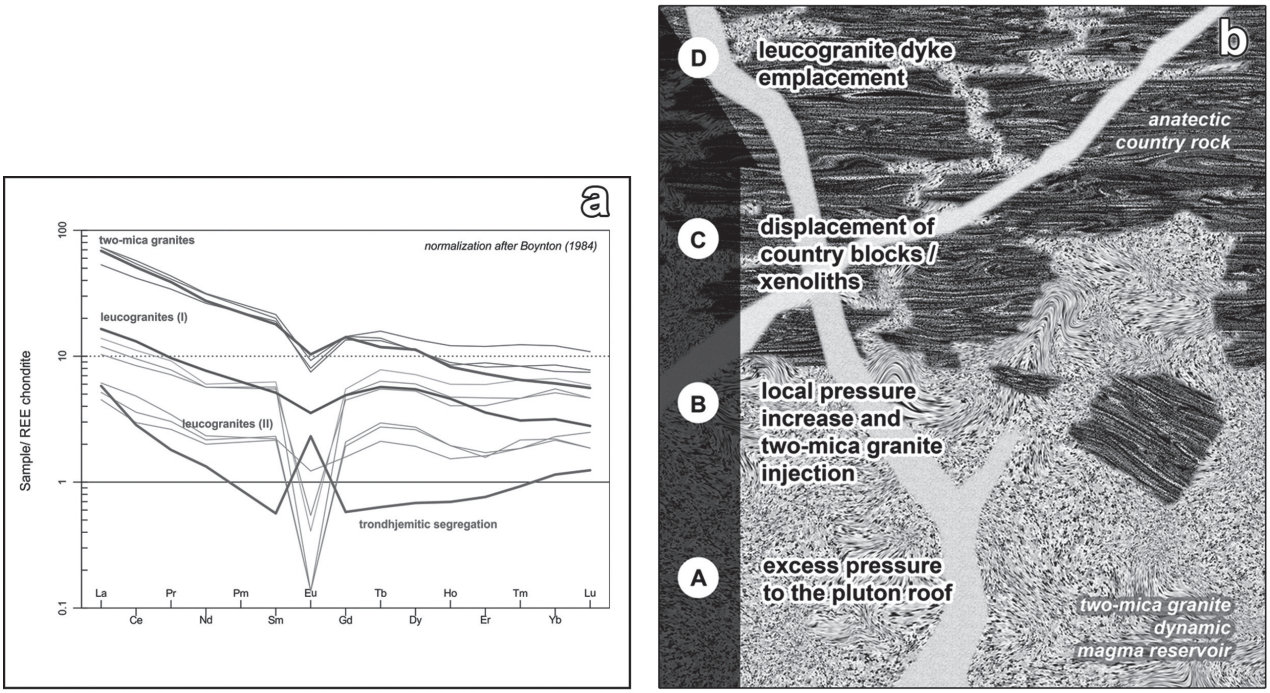

Figure 1. (a) REE patterns for leucocratic rocks from the Pleterac quarry compared to the typical MG granitoids (BALEN & BROSKA, 2011; BALEN & PETRINEC, 2011) are the best markers of different genetic and/or evolutionary histories of the three major leucocratic rock types. (b) Simplified model for the fragmentation of country rocks and development of metamafic xenoliths in Pleterac through stoping mechanism induced by the emplacement of the two-mica granite and followed by the intrusion of leucogranite dykes.

The uniformity of textural features throughout the amphibolite xenoliths in Pleterac, sharp discordant contacts between the blocks and the host granite, and the relative rotation of the blocks point to brittle behavior of the country rock during the intrusion of the two-mica granite body. On the other hand, subordinate leucogranites cross-cutting the two-mica granite and the metamafic blocks were emplaced subsequently through dyking mechanism (Fig. 1b). Our observations thus show that the stoping process was one of the mechanisms involved in emplacement of granitoid pluton at MG.

Keywords: *Moslavačka gora, stoping, pluton, trondhjemite, xenoliths*

References

BALEN, D. & BROSKA, I. (2011): Tourmaline nodules – products of devolatilization within the final evolutionary stage of granitic melt? Geological Society, London, Special Publications, 350, 53-68.

BALEN, D. & PETRINEC, Z. (2011): Contrasting tourmaline types from peraluminous granites: a case study from Moslavačka Gora (Croatia). Mineralogy and Petrology, 102, 117-134.

GLAZNER, A.F. & BARTLEY, J.M. (2006): Is stoping a volumetrically significant pluton emplacement process? GSA Bulletin, 118, 9/10, 1185-1195.

HARTEL, T.H.D. & PATTISON, D.R.M. (1996): Genesis of the Kapuskasing (Ontario) migmatitic mafic granulites by dehydration melting of amphibolite: the importance of quartz to reaction progress. Journal of Metamorphic Geology, 14, 591-611.

KOROLIJA, B. & CRNKO, J. (1985): Osnovna geološka karta SFRJ. List Bjelovar 1:100 000 L 33-82. Geološki zavod Zagreb (1975-1985), Savezni geološki zavod Beograd, Beograd.

PAMIĆ, J. (1990): Alpinski granitoidi, migmatiti i metamorfiti Moslavačke gore i okolne podloge Panonskog bazena (Sjeverna Hrvatska, Jugoslavija). Rad JAZU, knj. 10, 7-121.

Use of Ant-Tracking Attribute and Combined Seismic Volumes for Fault Identification: A Case Study From Sava Depression

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Advanced seismic interpretation today commonly implies transformation of original data into numerous seismic attributes. Identification of faults is associated with discontinuity of seismic reflectors. Therefore, during seismic interpretation, faults are usually defined through multi-trace seismic attributes such as variance, coherency, similarity, curvature, dip etc. These are called geometrical attributes because they help in defining the geometrical nature of seismic reflections. The ant-tracking attribute available in the Schlumberger Petrel software performs edge enhancement and uses a series of seismic attributes to identify and track faults through 3D seismic volume (PEDERSEN et al., 2002). The ant-tracking attribute requires complex processing of input data and selection of parameters during calculation. The input data for ant-tracking extraction is preprocessed seismic volume which includes smoothing (improves signal-to-noise ratio) and edge detection. The main step is further edge enhancement which generates the ant-tracking attribute volume and results in additional enhancement of the edges (faults) by suppressing noise and non-fault events.

The ant-tracking process and its advantages are presented on the example of 3D seismic data that cover wider area of Ježevo field in the Sava depression. The basic structure observed at the Ježevo oil field is an elongated anticline with two detached peaks. In the area of north-western peak, anticline is extended in the Dinaridic direction, and in the area of south-eastern peak, it slightly rotates towards ESE. The tectonic interpretation shows the flower structure. The reservoirs at this field are series of sandstones interbedded with marls. The ant-tracking attribute is expected to show better results in delineating faults and also to enable interpretation of faults that are hard to see on the 3D seismic data. In this study, spatial filtering of the seismic data has been done by applying structural smoothing. It reduces background noise and improves the lateral continuity of seismic data (RANDEN et al., 2000). Then, smoothed seismic data were converted to variance attribute as the input data for ant-tracking (Fig. 1). The other possibility is to use chaos attribute as input. In this study chaos emphasized not only faults but also chaotic textures within the seismic data, producing lower quality of the results. Ant-tracking workflow has been defined by a series of different parameters that determine how intelligent "artificial ants" will behave to capture the discontinuities in seismic data. It is important to set up parameters in accordance with the input data to obtain good data quality after processing.

The results were compared to other structural attributes, such as variance and chaos (Fig. 1). This study shows that variance attribute as an input for ant-tracking is more suitable to show major faults than the chaos attribute. Furthermore, a seismic calculator has been used to generate virtual volumes combined from original seismic data and variance as well as chaos attribute. New, combined seismic volume from variance attribute showed much clearer picture of the fault system than the classic variance attribute. Ant-tracking attribute, together with combined variance attribute, has been shown as the most valuable tool for interpretation of fault distribution and orientation in this study.

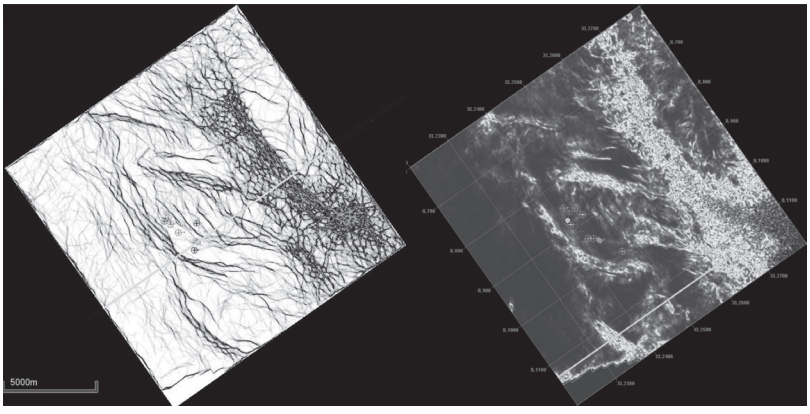

Figure 1. Time-slice of Ant-tracking attribute using structural smoothing and variance as input data (left) compared to simple variance attribute (right).

Keywords: fault detection, ant-tracking, variance attribute

References

PEDERSEN, S.I., RANDEN, T., SONNELAND, L. & STEEN, O. (2002): Automatic Fault Extraction using Artificial Ants, 72nd SEG International Conference, Salt Lake City, Annual Meeting Expanded Technical Program Abstracts, 72, 512-515.

RANDEN, T., MONSEN, M., SIGNER, C., ABRAHAMSEN, A., HANSEN, J.O., SAETER, T., SCHLAF, J. & SONNELAND, L. (2000): Three-Dimensional Texture Attributes for Seismic Data Analysis: SEG Annual International Meeting Expanded Abstracts, 668.

Petrographic and Diagenetic Characterization of Pre-Cretaceous Sedimentary Units in the Cesar Sub Basin (Colombia)

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The oil industry in Colombia has focused on the continuous search for hydrocarbon reserves, implementing studies in conventional and non-conventional deposits that generate interest in the exploration and commercial exploitation of hydrocarbons in the country, focusing on the evaluation of hydrocarbon potential in the Cesar-Ranchería basin (NATIONAL HYDROCARBONS AGENCY (ANH), 2019). The limited knowledge of geology in the Cesar-Ranchería Basin, (MESA & RENGIFO, 2011) has created the need to implement studies to find out the potential for generation, migration and entrapment of hydrocarbons within the basin, so that the characteristics and properties of the different elements that constitute the petroleum system, can be established. the characterization of the reservoir rock is a determining factor in the hydrocarbon prospection studies. MESA & RENGIFO (2011) focus on the calcareous and sandy intervals of the Carboniferous and Permian because their characteristics could favor the existence of reservoir and source rocks, making them attractive targets for the exploration of hydrocarbons in the Cesar Ranchería Basin.

The basal sandstones of the studied interval were analyzed using a combination of petrographic techniques in order to know the compositional and textural characterization of these rocks. These techniques are complemented with an analysis of electron scanning microscopy (SEM), which allows characterizing the clay minerals present in rocks, and how these are arranged on the grains of the rock and in its pore space. These methods allow us to characterize the processes and diagenetic products that have occurred in the post-depositional history of the rocks studied in the Cesar Ranchería Basin.

These sandstones, with fine to medium grain sizes, moderately selected, are classified as arches and lithic arches with porosity values ranging from 0.1–2.3% and permeability of 0.02–0.046 millidarcys (mD). These low values of porosity and permeability are controlled mainly by the mechanical compaction process, where a reorganization of the grains of the rock occurs, mechanical deformation of micas and rock fragments, as well as the presence of sutured and predominantly linear contacts. The precipitation of the cement also leads to a reduction in the porosity and permeability of these rocks (SANDOVAL, 2000), predominating carbonate cement, followed by silica cement, and low ferrous cement content. Other diagenetic products that can be evidenced in these sandstones are mainly: metasomatism of feldspar and plagioclase grains by carbonate and ferrous carbonate, seritization of plagioclase crystals and dissolution of feldspars and lithic fragments. Diagenetic minerals are also found such as illite from the group of clays, bordering the grains of the framework, which affect the petrophysical properties of porosity and permeability in these rocks.

Keywords: diagenesis, compaction, porosity, permeability, petrographic, Cesar Ranchería Basin

References

AGENCIA NACIONAL DE HIDROCARBUROS – ANH. (2019): La ANH le apuesta a proyectos Costa Afuera y a yacimientos en roca generadora para aumento de reservas. Consultado el 15 de abril de 2019.
http://www.anh.gov.co/Sala-dePrensa/ Lists/Anuncios/Noticias.aspx?ID=319&ContentTypeId=0x01040072853B5EA34F2842806117375623237C.

MESA, A. & Y. RENGIFO, S. (2011): Geologia del Petroleo de Colombian (Vol. 6). Medellin.

SANDOVAL, M. (2000): Diagénesis en Areniscas. Universidad Central de Venezuela, Consejo de desarrollo Científico y humanístico. Caracas.

Tectonic Evolution and Identification of Potential Seismogenic Sources of the Vinodol Valley (NW Adriatic, Croatia) Based on Geological Mapping and Structural Investigations

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The Vinodol valley is a NW–SE oriented valley parallel to the NE Adriatic coastline, whereas the area of Bakar bay represents its geomorphological and geological extension towards the NW. This complex, seismotectonically active area is characterised by prominent historical and instrumentally recorded seismicity. The area of the Vinodol valley and Bakar bay is a part of the greater geodynamic domain comprising the Ilirska Bistrica-Rijeka-Senj seismogenic fault zone. New geological and structural data in the study area were collected in order to better understand focal mechanisms of previous earthquakes and to possibly identify potential seismogenic sources. Conducted research in the Vinodol valley was focused on geological mapping accompanied with detailed structural-geological research of the valley and its continuation towards the NW into the Bakar bay area. This investigation together with new data on focal mechanisms of previous earthquakes could help in understanding the complex tectonic evolution of this area, including fault kinematics within identified potentially seismogenic structures. Mapped informal lithostratigraphic units mostly correspond to the Upper Cretaceous, Palaeogene and Quaternary successions described in other parts of the External Dinarides (e.g. GUŠIĆ & JELASKA, 1990; FUČEK et al., 2015).

Results of structural investigation generally correspond to previous studies and existing knowledge about the tectonic evolution of the area and Dinarides in general (e.g. BLAŠKOVIĆ, 2005 and references therein). However, the investigation resulted with several new important findings within the study area. The results of geological and structural investigations indicate a complex tectonic evolution of this area during Cretaceous, Palaeogene and Neogene, but also during the Quaternary. For example, the much shorter stratigraphic range of the youngest Upper Cretaceous unit, Gornji Humac fm. (of Upper Turonian age) in the Vinodol valley suggests that the uplifted area within the central NW part of the ancient Adriatic Carbonate Platform (for more details see VLAHOVIĆ et al., 2005 and references therein) at the end of the Turonian already comprised several thousands km^2 (from W and NW Istria to the Krk and Vinodol area). An additional new finding in the study area is that along SW-vergences typical for the Dinarides there are common NE-vergent reverse structures, especially along the SW margin of the Vinodol valley. Cross-cutting relationships suggest that transpressional (NW–SE and NE–SW striking dextral and sinistral faults) and extensional features (NW–SE and NE–SW striking normal faults) are structurally concurrent or younger than compressional ones (reverse faults), indicating a change in the palaeostress field during Neogene–Quaternary, resulting in prevalent transpression and radial extension.

Comparison of palaeostress field analysis and constructed synthetic focal mechanism with available data on focal mechanism solutions within the Ilirska Bistrica-Rijeka-Senj seismogenic fault zone (FMS-database, 2019; HERAK et al., 2017, 2018 and references therein) show favourable orientation of observed NW–SE and NE–SW striking faults in respect to the present compressional/transpressional stress field (N–S oriented P-axis), indicating them as potential seismogenic sources within the study area.

Acknowledgements

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Keywords: Vinodol valley, compression/transpression, neotectonic activity, focal mechanism solutions, seismicity

References

BLAŠKOVIĆ, I (2005): Geologija Vinodola (Geology of Vinodol). In: BIONDIĆ, R., VLAHOVIĆ, I. & VELIĆ, I. (eds.): 3. Hrvatski geološki kongres (Third Croatian Geological Congress), Vodič ekskurzija (Excursion Guide-Book), 39–48, Zagreb.

FMS-Database (2019): Database of Focal Mechanism Solutions. Archives of the Department of Geophysics, Faculty of Science, University of Zagreb.

FUČEK, L., MATIČEC, D., VLAHOVIĆ, I., OŠTRIĆ, N., PRTOLJAN, B., KOROLIJA B., KORBAR, T., HUSINEC, A. & PALENIK, D. (2015): Osnovna geološka karta Republike Hrvatske mjerila 1:50.000 – list Cres i Lošinj (Basic Geolo-

References

gical Map of the Republic of the Croatia 1:50,000 Scale – Cres and Lošinj sheet). Hrv. geol. inst., ISBN: 978-953-6907-53-3, Zagreb.

GUŠIĆ, I. & JELASKA, V. (1990): Stratigrafija gornjokrednih naslaga otoka Brača u okviru geodinamske evolucije Jadranske karbonatne platforme (Upper Cretaceous stratigraphy of the Island of the Brač). Jugosl. akad. znan. i umjet., Institut za geološka istraživanja, OOUR za geologiju, 160 p., Zagreb.

HERAK, D., SOVIĆ, I., CECIĆ, I., ŽIVČIĆ, M., DASOVIĆ, I. & HERAK, M. (2017): Historical seismicity of the Rijeka region (Northwest External Dinarides, Croatia) – Part I: Earthquakes of 1750, 1838, and 1904 in the Bakar epicentral area. Seismol. Res. Lett., 88/4, 1–12, doi: 10.1785/0220170014.

HERAK, M., ŽIVČIĆ, M., SOVIĆ, I., CECIĆ, I., DASOVIĆ, I., STIPČEVIĆ, J. & HERAK, D. (2018): Historical seismicity of the Rijeka region (NW External Dinarides, Croatia) – Part II: The Klana earthquakes of 1870. Seismol. Res. Lett., 89/4, 1524–1536, doi:10.1785/0220180064.

VLAHOVIĆ, I., TIŠLJAR, J., VELIĆ, I. & MATIČEC, D. (2005): Evolution of the Adriatic Carbonate Platform: paleogeography, main events and depositional dynamics. Palaeo., Palaeo., Palaeo., 220, 333-360.

Hydrogeological Characteristics of the Rakovac Spring Recharge Area, Mt. Žumberačka Gora

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The recharge area of the Rakovac spring is located north – northeast from the spring on the southwestern slopes of Štipkovo Hill (Mt. Žumberačka gora). Within the recharge area of the Rakovac spring, based on the hydrogeological characteristics and hydrogeological function, rocks are distinguished into two groups. In the first group are the high permeable intensively tectonized Upper Triassic dolostone deposits that form the main aquifer. To the second group belong medium permeable Jurassic (dolomitic limestone, limestone, calcarenite) and Upper Cretaceous deposits ("Scaglia" limestone) with the role of barrier to the groundwater flow. The cover deposits on the entire surface of the recharge area are thin and permeable forest soils. The recharge of the aquifer is provided by more intensive infiltration of the precipitation into higher areas of the terrain (above 700 m a.s.l.) characterized with well-developed typical karstic forms (sinkholes), thus reduce the possibility of surface drainage and increase effective infiltration. The discharge of the aquifer takes place at one permanent and descending type of spring and at two more intermittent springs whose occurrence is related exclusively to wet seasons when groundwater levels are high (Fig. 1). All springs are located on the hypsometrically lower contacts of the carbonate aquifer with the less permeable deposits and are the places of spilling the "surplus" of the groundwater that accumulates by the infiltration of precipitation.

The Rakovac spring occurs in the tectonized dolostones in which the preferential flow paths of groundwater flow are developed, i.e. aquifer probably discharges through a well-developed conduits. The Rakovac spring never dries which suggests a sufficiently large aquifer with a certain storage capacity due to a finely tectonized dolostone (fracture porosity). The facts that discharge at the spring increases rapidly and the water becomes muddy after a heavy rain refer to presence of cavernous porosity besides fracture porosity. Fast response of spring on rainfall event, i.e. rapid

(a) (b)

Figure 1. The Rakovac spring during dry (a) and wet period (b).

changes of discharge, also indicate the good hydraulic connection between the surface and aquifer. The ratio of minimum and maximum discharge is 1:520 which is similar to the typical karst springs. According to basic chemical composition of the spring water, the Rakovac spring belongs to CaMg-HCO_3 type, due to the mainly dolomite dissolution process. Content of magnesium ion is lower than expected, indicating that some parts of aquifer are in contact with limestones or composed of limestones. The hydrogeochemical facies of spring is constant throughout the year what implies drainage from fracture system regardless of storms and wet and dry periods. Water is generally of a good quality, but the influence of anthropogenic pollution is noticed. Water is the most burdened with microbiological contamination. The main reason is the lack of sewerage system in the Poklek and Podigrišće settlements located less than 1000 m north of the Rakovac spring (in the zone with developed karstic forms and the largest effective infiltration), so waste water from the houses and stables can reach the aquifer fast and easy.

Keywords: *hydrogeological characteristics, spring Rakovac, Mt. Žumberačka gora, recharge area*

Cordierite-Producing Reactions in Anatectic Rocks from Moslavačka Gora (Croatia)

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Cordierites (Crd) with idealized composition $(Mg,Fe)_2[Al_4Si_5O_{18}]*n(H_2O,CO_2)$ occur as a characteristic, usually accessory phase in many types of felsic peraluminous igneous rocks, but also in medium- to high-grade metamorphic aluminous rocks of amphibolite and granulite facies (BERTOLDI et al., 2004). This is because stability fields of cordierite in the p-T-X space embraces both, normal metamorphic and igneous domains (CLARKE, 1995).

Metamorphic rocks of Moslavačka Gora (MG) often contain cordierite (e.g. BARIĆ, 1954; KOROLIJA et al., 1986; VRAGOVIĆ & MAJER, 1979). PAMIĆ (1990) reports frequent occurences of cordierite in amphibolite facies schists and to a lesser extent in migmatites. GARAŠIĆ (1993) recognizes the complexity of cordierite-bearing rocks and defines them as polymetamorphic. In the MG granites, unaltered cordierite is rarely present (e.g. PAMIĆ, 1990; STARIJAŠ et al., 2010; PETRINEC, 2013).

We have conducted a systematic study of cordierite-bearing aluminous metamorphic rocks from typical MG localities mentioned in the literature (Jaska creek, Tičar creek, Garjevica, Kamenjača-Stelovača, Kamenac). They all show clear foliations, at least on a microscale. Typical paragenesis includes Als (Sill/And), Qtz, Fsp, Bt (± Ms), Crd (Grt ± Spl), secondary and accessory phases. According to microstructural characteristics and observed mineral reactions, all of the studied rocks have been determined as anatexites, with a distinct signature of melt generation and its segregation into specific microstructural domains (PETRINEC, 2013).

Based on the microstructural characteristics and further supported by chemical data, two major types of cordierite are defined: prograde (Type I) retrograde (Type II) cordierite. The prograde cordierite from the mesocratic domains forms porphyroblasts elongated in the plane of the main foliation (Type Ia). Most of these Crd porphyroblasts are rimmed by biotite and envelope a partly resorbed alumosilicate core (And/Sill), pointing to Crd production through biotite dehydration melting reaction: And + Bt I + Pl I + Qtz = Crd (Ia) + Kfs + Bt II + Pl II + (Ilm) + melt (PETRINEC, 2013). This type is regarded as peritectic cordierite (CLARK, 1995; GROPPO et al., 2013).

Garnet- and cordierite-bearing anatexites host another microstructural subtype of prograde cordierite (Type Ib) related to melting reaction including garnet (ÁLVAREZ-VALERO et al., 2007). It encompasses Crd+Spl aggregates developed around partly resorbed Grt grains formed through reaction: Grt + Sil + Bt + Pl = Crd (Ib) + Spl + Kfs + melt (PETRINEC, 2013).

Third type of prograde cordierite (Type Ic) is cotectic cordierite (CLARKE, 1995, GROPPO et al., 2013) that occurs in the leucocratic (micro) domains of the samples. It forms subhedral grains with rare biotite and quartz inclusions pointing to growth during melt crystallization i.e. at decreasing temperature, through the reaction: melt → Qtz + Kfs + Crd + V.

In garnet-bearing samples, cordierite pseudomorphs after garnet are also observed (Type II) which are indicative for back reaction of garnet with the co-existing melt that took place along the retrograde p-T path. Preservation of

biotite and its presence as inclusion inside Crd grains, interstitial character of K-feldspar inside the pseudomorphs together with other microstructural characteristics point to reaction: Grt (± Spl) + melt = Crd (II) + Bt + Pl + Kfs (PETRINEC, 2013).

Due to its mineralogy i.e. the facility to incorporate and/or release volatiles from its structure, cordierite is easily altered whenever it leaves its own p-T-X stability field (CLARKE, 1995). In the MG anatexites, variable extent of cordierite alterations is observed. Type Ia and Ib cordierites are generally well-preserved, almost free of hydrous retrogression. Type Ic cotectic cordierite from the leucosomes is partly retrogressed and replaced by fine-grained white mica±chlorite/biotite aggregates (pinnite) along grain boundaries. These observations also corroborate the fluid-saturated (sub)system for the formation of cotectic cordierite (Type Ic) while other (sub)types formed in "dry" conditions.

The observations from anatectic rocks of Moslavačka Gora point to multiple cordierite-producing reactions, all of them closely related to production of peraluminous melt in these rocks. Additionally, the presence of cotectic i.e. magmatic cordierite in MG anatexites represents a probable connection with peraluminous cordierite-bearing granites emplaced into the shallow crustal level of the Late Cretacous Adria-Europe plate boundary setting.

Keywords: Moslavačka Gora, anatexis, peritectic cordierite, cotectic cordierite

References

ÁLVAREZ-VALERO, A.M., CESARE, B. & KRIEGSMAN, L.M. (2007): Formation of spinel-cordierite-feldspar-glass coronas after garnet in metapelitic xenoliths: reaction modelling and geodynamic implications. Journal of Metamorphic Geology, 25, 305-320.

BERTOLDI, C., PROYER, A., GARBE-SCHÖNBERG, D., BEHRENS, H. & DACHS, E. (2004): Comprehensive chemical analyses of natural cordierites: implications for exchange mechanisms. Lithos, 78, 389-409.

BARIĆ, Lj. (1954): Biotitno-kordijeritni škriljavac s andaluzitom i silimanitom iz Jaske potoka u Moslavačkoj gori. Geologija, 2, 145-157.

CLARKE, D.B. (1995): Cordierite in felsic igneous rocks: a synthesis. Mineralogical Magazine, 59, 311-325.

GARAŠIĆ, V. (1993): Uvjeti metamorfizma stijena amfibolitnog facijesa Moslavačke gore [Conditions of amphibolite-facies metamorphic rocks from Moslavačka Gora – In Croatian]. Unpubl. MSc Thesis, University of Zagreb, 142 p.

GROPPO, C., ROLFO, F. & MOSCA, P. (2013): The cordierite-bearing anatectic rocks of the higher Himalayan crystallines (eastern Nepal): low-pressure anatexis, melt productivity, melt loss and the preservation of cordierite. Journal of Metamorphic Geology, 31, 187-204.

KOROLIJA, B., VRAGOVIĆ, M., CRNKO, J. & MAMUŽIĆ, P. (1986): Osnovna geološka karta 1:100 000. Tumač za list L 33-82 Bjelovar [Basic Geological Map of Yugoslavia in scale 1:100.000. Explanatory notes for sheet L 33-82 Bjelovar]. Geološki zavod Zagreb (1985), Savezni geološki zavod Beograd, Beograd.

PAMIĆ, J. (1990): Alpine granitoids, migmatites and metamorphic rocks from Mt. Moslavačka Gora and the surrounding basement of the Pannonian Basin (northern Croatia, Yugoslavia). Rad JAZU, 10, 7-121.

PETRINEC, Z. (2013): Strane i kognatne enklave u krednim granitoidima Moslavačke gore: mikrostrukturni i geokemijski uvid u kompleksnu evoluciju moslavačkog kristalina [Foreign and cognate enclaves inside Cretaceous granitoids: microstructural and geochemical insight into complex evolution of the Moslavačka Gora crystalline – In Croatian]. Unpubl. PhD Thesis, Faculty of Science, University of Zagreb, 264 p.

STARIJAŠ, B., GERDES, A., BALEN, D., TIBLJAŠ, D. & FINGER, F. (2010): The Moslavačka Gora crystalline massif in Croatia: a Cretaceous heat dome within remnant Ordovician granitoid crust. Swiss Journal of Geosciences, 103, 61-82.

VRAGOVIĆ, M. & MAJER, V. (1979): Prilozi za poznavanje metamorfnih stijena Zagrebačke gore, Moslavačke gore i Papuka (Hrvatska, Jugoslavija). Geološki vjesnik, 31, 295-308.

Sedimentology of Istrian Flysch Megabeds

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The Istrian Foreland basin was formed during the Eocene period in collisional processes between the Adria microplate and the Eurasian plate as a foredeep depozone in front of the migrating Dinaridic wedge (KORBAR, 2009). Its sedimentary fill consists of Foraminiferal limestones, Transitional beds (Globigerina marls) and Istrian flysch which represent the lower, middle and upper unit of the underfilled peripheral foreland basin, respectively (SINCLAIR, 1997; OTONIČAR, 2007). The distinct packages within the Istrian flysch are interpreted as deposits of deep sea environments, either distal fan or base of the slope.

Istrian flysch is characterized by the alternation of hemipelagic marls and gravity-flow deposits (BERGANT et al., 2003). The gravity-flow deposits are 5–40 cm thick turbidites, developed mostly as plane-parallel laminated and cross-laminated sandstone beds (shale-sandstone/siltstone couplets without a Bouma Ta division). Complete Ta-e Bouma sequences are rare. Sandstones are of mixed carbonate-siliciclastic composition. The monotonous succession of marls and mixed carbonate-siliciclastic sandstones is intercalated with several thick carbonate beds composed of breccias, conglomerates, calcarenites/calcsiltites and marls. They show significant thickness, occasionally more than 10 m (BERGANT et al., 2003). These carbonate beds are interpreted as complex single event deposits, composed of rockfall and avalanche deposits, debrites and turbidites and are labeled as Megabeds. Some of them become thinner and pinch out laterally, but thicker ones are continuous over distances of more than 10 km.

Here, we describe Istrian flysch megabeds and present their variations, mechanisms and environments of their deposition. For this purpose several sedimentological sections in Central Istria and Labin area have been documented and are presented here. Most megabeds have normally graded, clast supported breccias/conglomerates in the lower part, with up to boulder-size clasts. This part of megabed was deposited by a rockfall or a debris flow. The composition of lower part clasts are: Cretaceous limestones, different lithofacies types of Foraminiferal limestones, bioclasts, skeletal fragments of large benthic foraminifera (nummulites and orthophragminides), calcarenites and marl clasts (rip-up clasts). This features imply a short transport and base of the slope environment. The upper part of the megabed is a turbidite, suggesting flow transformation into high-density turbidity current (HAUGHTON et al., 2009). The thickness of these two parts can vary greatly. Clast composition of the upper, turbidite part is similar, but clasts are smaller and mainly composed of bioclasts and skeletal fragments of large benthic foraminifera (Nummulitic breccia). The turbidite parts show normal grading into calcarenites. Furthermore, some megabeds have only the turbidite part which in some cases can be thick up to 5 m. The provenance of megabed material is from Istrian foreland ramp.

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Keywords: *turbidity current, concentrated density flow, rockfall, composite bed, foreland basin, Dinarides*

References

BERGANT, S., TIŠLJAR, J. & ŠPARICA, M. (2003): Eocene Carbonates and Flysch Deposits of the Pazin Basin. in: VLAHOVIĆ, I. & TIŠLJAR, J. (eds.): Field Trip Guidebook – 22nd IAS Meeting of Sedimentology – Opatija 2003. Zagreb, Croatia: Croatian Geological Survey. 57-63.

HAUGHTON, P., DAVIS, C., MCCAFFREY, W. & BARKER, S. (2009): Hybrid sediment gravity flow deposits – Classification, origin and significance. Marine and Petroleum Geology, 26, 1900-1918.

KORBAR, T. (2009): Orogenic evolution of the External Dinarides in the NE Adriatic region: a model constrained by tectonostratigraphy of Upper Cretaceous to Paleogene carbonates. Earth-Science Reviews, 96, 296-312.

OTONIČAR, B. (2007): Upper Cretaceous to Paleogene forebulge unconformity associated with foreland basin evolution (Kras, Matarsko podolje and Istria; SW Slovenia and NW Croatia). Acta Carsologica, 101-120.

SINCLAIR, H.D. (March 1997): Tectonostratigraphic model for underfilled peripheral foreland basins. GSA Bulletin, 109(8), 324-346.

Geological Model of Pićan Area, Istria

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During geological mapping of Istria (Croatia) numerous carbonate beds (megabeds) were recorded within the informal lithostratigraphic unit Istrian flysch. Istrian flysch deposits are mostly characterized by typical alternations of hemipelagical marl and gravity-flow deposits (BERGANT et al., 2003). The monotonous succession of marl and mixed carbonate-siliciclastic sandstone is intercalated with several relatively thick carbonate beds - megabeds, composed of breccia, conglomerate, bioclastic arenite/siltite and marl. The thickness of these megabeds varies between 0.5–5 m, rarely over 10 m. The megabeds are interpreted as complex sequences of rockfall, debrite and turbidite deposits, characteristic for the lower part of the basin fill (BERGANT et al., 2003). In eastern Istria, near the town of Pićan, an unusual carbonate layer is mapped, named "Pićan bed", whose genesis cannot be explained by

the depositional mechanisms of turbidite currents or debris flows, characteristic for the Istrian Flysch deposits. For this purpose, a more detailed field investigation was performed and a sedimentary log (Pić-I) was recorded within a tectonically undisturbed succession of Paleogene deposits. At the base of the succession an informal lithostratigraphic unit "Foraminiferal limestone" gradually transitions into "Marls with Crabs" and further into "*Globigerina* marls" informal lithostratigraphic units. The interval of massive "*Globigerina* marls" is approx. 100 m thick and transitions into the Istrian flysch lithostratigraphic unit, here represented with this unusual "Pićan bed". Flysch deposits are composed of calcarenite beds, marl, sandstone, and, of course, megabeds are well documented in the surrounding area. The sedimentary log was used to complement the new lithostratigraphic map of the area (PETRINJAK et al., 2018).

The geological model of the Pićan area was built based primarily on the lithostratigraphic map and geological cross-sections, and the Digital Surface Model (DSM) of the area. The data were modelled using Midland Valley Move geological modelling software. The new lithostratigraphic map together with other available data, such as Digital Orthophoto Images of the area were used to construct a series of geological cross-sections needed for the model, while an Unmanned Aerial Vehicle (UAV) was used to record the DSM of the area.

Finally, the geological model of the Pićan area displays, faithfully as possible, the spatial distribution of the "Pićan bed" and the interesting geological setting of the Pićan area, Istria.

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Keywords: *geological mapping, 3D geological modelling, flysch, megabeds*

References

BERGANT, S., TIŠLJAR, J. & ŠPARICA, M. (2003): Eocene Carbonates and Flysch Deposits of the Pazin Basin. In: VLAHOVIĆ, I. & TIŠLJAR, J. (eds.): 22nd IAS Meeting of Sedimentology, 17-19. September, 2003, Opatija, Croatia, Field Trip Guidebook , Croatian Geological Survey, Zagreb. 57-63.

PETRINJAK, K., BERGANT, S., KUREČIĆ, T. & AŠČIĆ, Š. (2018): Possible occasional recovery of carbonate sedimentation within Istrian flysch basin. In: NOVAK, M. & RMAN, N. (eds.), 5th SLOVENIAN GEOLOGICAL CONGRESS 3–5. October, 2018, Velenje, Book of abstracts. Geological Survey of Slovenia, Ljubljana, p. 124.

Impact of the Sediment Characteristics on the Organic Matter Content Under the Various Types of Fish Farms

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Aquaculture is today the fastest growing food-producing sector currently providing about 50% of the world's fish foods (FAO, 2019). However, its rapid development and intensity revealed various environmental issues. In particular, fish farming affect the benthic environments by organic matter (OM) accumulation. As the result hypoxic and anoxic conditions may occur, leading to toxic gases production and remobilization of trace metals. Progressively changed sedimentary environment may thus act as a source of contaminants, further reducing water quality and affecting the food web. In order to prevent environmental deterioration a proper site selection is a prerequisite for sustainable aquaculture practice.

One of the key physical factors when it comes to fish farm site selection is sediment structure: sandy and gravelly sediment is preferred, suggesting appropriate lateral water transport. In order to examine unknown relationships between sediment characteristics that may affect the pro-

portion and the retention of the OM in the bottom, sediment from three different locations of various aquaculture practices were examined. Sediment was sampled quarterly during one year. Grain size was determined by the combined methods of wet sieving and sedigraph. OM content was calculated by the loss of ignition (LOI). Bulk sediment mineral composition was determined by the x-ray diffraction, while carbonate content was determined by CO_2 volumetry. Obtained results were compared with sediment sampled in referent locations paired with each farm site.

The sediment samples under marine cage-type fish farm in the Mali Ston Bay were in general slightly finer (gravelly sands, sandy gravels and muddy gravel) compared to the referent sampling location (gravelly sands and sandy gravel). The mud content was consistently low (<5%) in both locations, except below the cages after autumn sampling (~50%). Carbonate content was consistently high (>90%) in both locations, with the same exception below cages after autumn sampling (>50%). In accordance with the grain size distribution and the carbonate content, sediment was dominated by calcite, Mg-calcite, and aragonite, typical for the eastern Adriatic shelf (PIKELJ, 2010). OM content in sediment in both locations was equal and varied between 2.9-8.2 %, which is comparable with other results from the middle and southern Adriatic (MATIJEVIĆ et al., 2008a; b). The exception is 11.5% of OM below cages found during spring sampling. This result may be the consequence of enhanced input of the Neretva River carrying OM and nutrients from its highly anthropized delta. Suspiciously muddy sediment sampled under the cage in autumn and with only 50% of carbonates is being considered to reflect local variations in seabed morphology (eg. depression), which may affect grain size distribution (PIKELJ, 2010). This conclusion is underpinned by the fact that despite the high share of mud (~50%) the OM content in this particular sediment was relatively low (4.7%).

Fish farm on the Krka River is pool type with flowing water. Its sediment was classified mostly as sandy gravels as well as the river sediment on the referent location. Small changes in grain size together with carbonate content on both location were ascribed to the sediment flow within the river system. Dominating minerals were calcite and dolomite with quartz to the lesser extent, reflecting the surrounding lithology, dominated by Mesozoic dolomites and limestones with Holocene proluvial and alluvial deposits (CGS, 2009; VELIĆ & VLAHOVIĆ, 2009). OM content in sediment from the farm was constant (~ 4%) during the monitored period, as well as on the referent location (~1.5%). Bearing in mind the fact that the control point is situated immediately downstream of the fish pools, it is likely that the impact of the fish farm was localized to the farm pools.

Fish farm on the Ilova River includes ponds separated by natural or constructed barriers, while the chosen referent location is within the Ilova River. Sediment from the pond were determined as gravelly muds and muddy gravels, with average mud content of 35%. A much higher share of mud (~90%) was found in sediment sampled on the referent location and characterized as mud or sandy mud. Carbonates were almost absent from the river sediment, while pond sediment revealed about 30% of carbonates. Based on the grain size and the carbonate share a higher percentage of the OM was expected. However, its consistent percentage of 4% in ponds and of 6% in river was unexpectedly low. The explanation of obtained results was found in the mineral composition. Quartz is the dominant mineral phase in both locations. Plagioclase and feldspars are less abundant, as well as muscovite. Clay minerals found on both locations are scarce and belong to the kaolinite group, while relatively high carbonate content in ponds may be the result of accumulation and/or local biogenic production (eg. bivalves). In general, mineral composition reflects the surrounding lithology dominated by loess (CGS, 2009; VELIĆ & VLAHOVIĆ, 2009).

As shown in above-described case studies of three different fish farm practices performed in various climatic and environmental conditions, grain size is proven as one of the key factors defining the fate of the OM in bottom sediment. However, as shown in case of muddy marine sediment and the muds in the Ilova River, mineral composition is another important sediment characteristic to be considered when choosing a location for a fish farm. In particular, mineral composition of fine-grained fractions has to be known when it comes to environmental studies, as already emphasized by PIKELJ et al. (2016).

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Keywords: fish farm, sediment, environmental health, mineral composition, organic matter

References

CGS (2009): Geological Map of Republic of Croatia, M 1:300.000. Croatian Geological Survey, Department for Geology, Zagreb.

FAO (2019): www.fao.org/fishery/aquaculture/en

MATIJEVIĆ, S., KUŠPILIĆ, G., KLJAKOVIĆ-GAŠPIĆ, Z & BOGNER, D. (2008a): Impact of fish farming on the distribution of phosphorus in sediments in the middle Adriatic area. Mar. Pollut. Bull., 56, 535-548.

MATIJEVIĆ, S., BOGNER, D., MOROVIĆ, M., TIČINA, V. & GRBEC, B. (2008b): Characteristics of the sediment along the Eastern Adriatic coast (Croatia). Fresen. Environ. Bull., 17, 10b, 1763-1772.

PIKELJ, K. (2010): Sastav i porijeklo površinskog sedimenta istočne strane Jadranskog mora [Composition and origin of seabed sediments of the eastern part of the Adriatic Sea – in Croatian, with an English Abstract]. Unpubl. PhD Thesis, Faculty of Science, University of Zagreb, 239 p.

PIKELJ, K., JAKŠIĆ, L., AŠČIĆ, Š. & JURAČIĆ, M. (2016): Characterization of the fine-grained fraction in the surface sediment of the eastern Adriatic channel areas. Acta Adriat., 57/2, 195-208.

VELIĆ, I. & VLAHOVIĆ, I. (eds.)(2009): Explanatory notes for the geological map of the republic of Croatia in 1:300,000 scale. Croatian Geological Survey [in Croatian], 141 p.

Hydrogeological Investigations in Loess: The ISSAH Project

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Loess is a widespread, fine grain, aeolian deposit covering approximately 10% of the global surface (MUHS, 2007). Loess areas are suffering an increasing anthropogenic pressure related to: (i) the excavation of the deposits for construction purposes, and (ii) the agricultural importance of loess-derived soils related to their inherent fertility. Groundwater is the most important resource of potable waters in these areas where both the amount and quality of surficial waters can be scarce (LI & QIAN, 2018). In this context, loess represents the low permeable barrier separating the potable exploited resource from the surficial waters, whose quality could be further compromised by agriculture. The geological processes that form loess from the erosion of the original rock and the sediment mobilization by wind to its final deposition and the further post-depositional modifications have been widely studied employing sedimentological, geochemical, and geochronological approaches. These processes determine the mechanical and hydrogeological characteristics of loess, which have been researched far less frequently.

The ISSAH project funded by the Croatian Science Foundation (project number: UIP-2017-05-9345) investigates loess in eastern Croatia, where both the described hydrogeological setting and the anthropic pressure issues occur. The employed multidisciplinary approach integrating hydrogeology, hydrogeochemistry, and pedology with the classical sedimentological analyses is beneficial to assess the impact of depositional and post-depositional processes on loess hydrogeological behaviour. The research is conducted in three areas (i.e. Baranja, Srijem, and Eastern Slavonia) where the deposits extensively crop out and their sedimentological and geochemical features are well-established (GALOVIĆ et al., 2009; GALOVIĆ, 2016). Medium to coarse silt is the representative grain size, but intercalations of sands can be found locally. This granulometric distribution suggests a low effective porosity (5-9%) resulting in hydraulic conductivities between 10^{-9} and 10^{-6} m/s. However, post-depositional processes can locally increase the bulk hydraulic conductivity. In addition to neotectonic features, polygonal cracks produced by hydroconsolidation and vertical or subvertical root channels are common discontinuities in loess (BARTA, 2011; SMALLEY et al., 2016). The occurrence of secondary carbonates and iron minerals at the border of root channels corroborates their role as preferential flow paths. Despite microscopic scale evidence, the hydraulic impact of these discontinuities has not been quantified.

Firstly, the regional geological and hydrogeological settings will be updated reconstructing the vertical and horizontal contacts between sandy and loess deposits (aquifer and aquitard, respectively). Afterwards, three boreholes will be drilled in selected locations and detailed geological and hydrogeological investigations will be conducted obtaining a micro- to macroscale (i.e., sample to borehole) hydrogeological conceptual model of loess deposits. The reconstruction will be accompanied by pedological analyses and the collection of local meteorological data (i.e., temperature, precipitation, evapotranspiration, soil moisture, etc.) unravelling the local water cycles. These data will be integrated into the updated regional hydrogeological settings favouring the upscaling of the proposed conceptual model to regional scale.

The results of this study will be beneficial for: (i) a broad comprehension of loess through a multidisciplinary approach that investigates both the geological and engineering geological aspects of the deposits, and (ii) the progression of the hydrogeological knowledge on aquitards, considering the established correlations between the specific surface area, the particle size distribution, and the hydrogeological and pedological properties of fine-grained materials.

Keywords: *loess, depositional and post-depositional processes, hydrogeological conceptual modelling, eastern Croatia, Croatian Science Foundation*

References

BARTA, G. (2011): Secondary carbonates in loess-paleosoil sequences: a general review. Open Geoscience, 3, 129-146.

GALOVIĆ, L. (2016): Sedimentological and mineralogical characteristics of the Pleistocene loess/paleosol sections in the Eastern Croatia. Aeolian Research, 20, 7-23.

GALOVIĆ, L., FRECHEN, M., HALAMIĆ, J., DURN, G. & ROMIĆ, M. (2009): Loess chronostratigraphy in Eastern Croatia – A luminescence dating approach. Quaternary International, 198, 85-97.

MUHS, D.R. (2007): loess deposits, origins and properties. In: ELIAS, A. (eds.): Encyclopedia of Quaternary Science, 1405-1418.

References

LI, P., & QIAN, H. (2018): Water resource development and protection in loess areas of the world: a summary to the thematic issue of water in loess. Environmental Earth Sciences, 77(24), 796.

SMALLEY, I.J., BENTLEY, S.P. & MARKOVIC, S.B. (2016): Loess and fragipans: Development of polygonal-crack-network structures in fragipan horizons in loess ground. Quaternary International, 399, 228-233.

GeoTwinn – Twinning of the European Geological Surveys

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The GeoTwinn is the Horizon 2020 Twinning project funded by European Commission and is fully entitled: Strengthening research in the Croatian Geological Survey: Geoscience-Twinning to develop state-of-the-art subsurface modelling capability and scientific impact. The project twins the Croatian Geological Survey (HGI-CGS) with two world-leading geoscience research institutions: the Geological Survey of Denmark and Greenland (GEUS) and the British Geological Survey of the United Kingdom Research and Innovation (BGS-UKRI).

The Project has started in October 2018, and is coordinated by HGI-CGS. The major aims of the project are: to significantly strengthen HGI-CGS's research potential and capability, networking between scientists and institutions, and also development of ideas and new projects proposals. During three years of implementation, HGI-CGS experts will have the opportunity to collaborate with eminent scientists from other two partnering institutions. HGI-CGS will also benefit from a range of research tools, technologies, software and methods at the disposal of GEUS and BGS-UKRI. Almost thirty scientists from HGI-CGS will participate in the training programme which includes intensive training, consultations, and application of gained knowledge on test areas/data. The program involves short term visits, two-way scientific exchanges and workshops which will support HGI-CGS to strengthen research and capabilities in four important geoscience subject areas (Fig. 1):

(1) 3D geological surveying and modelling (WP1) – to embed state-of-the-art geological surveying, interpretation and modelling. In the first activity, modern digital geological workflow and subsurface modelling capabilities including 3D virtual reconnaissance will be introduced. Also, digital field data capture, geological databases and 3D geological modelling are introduced. The second activity will reinforce these 3D visualisation and modelling skills by applying them to pilot areas using deep seismic reflection and borehole data.

(2) advanced groundwater flow and contaminant transport modelling (WP2) – to understand, simulate and predict the movement of groundwater and contaminants in the subsurface. It comprises two activities, the first of which deals with strengthening HGI-CGS's capacity to undertake cutting-edge numerical groundwater flow in porous aquifers, incorporating the robust assessment of uncertainty. The second activity deals with groundwater flow in the karst aquifers of Dinaric karst region of Croatia using advanced statistical time-series analysis methods. It will also introduce research methods to identify and analyse emerging groundwater contaminants.

(3) identification and analysis of geohazards (WP3) – to introduce cutting-edge remote sensing methods for hazardous geological processes detection, monitoring and analysis. Training also includes the interpretation and visualisation of stereo imagery, processing of satellite imagery, INSAR interferometry and satellite detection of small-scale movements. The project also contains training on heuristic, statistical and geostatistical techniques to enable production of landslide susceptibility mapping.

(4) geothermal energy (WP4) – scientific exchanges and training that will lead to new research into geological controls on subsurface heat flow and geochemical processes operating in hydrothermal systems. HGI-CGS staff will attend training on sampling and analytical methods of noble and dissolved gases from hydrothermal systems. The training is also directed toward interpretation of hydrochemical data and geochemical modelling of hydrothermal systems. Second segment of the training develops fluid and heat flow modelling capability through numerical modelling of geothermal systems.

The project will increase the research capacity, excellence and skill of the coordinating partner whilst fostering a network of both early career and more experienced re-

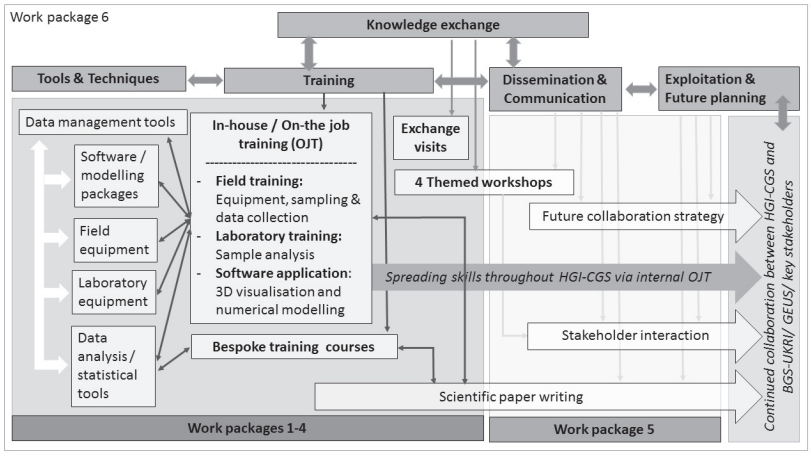

Figure 1. Overall Twinning approach, key twinning elements, activities and interdependencies.

searchers who can collaborate to produce high quality and impactful results:

- a step-change in the excellence and impact of the research published HGI-CGS staff;
- raise the reputation and the research profile of HGI-CGS scientists for novel research;
- enhance research and innovation related to environmental issues, including the need for a shift to a low-carbon economy, climate change adaptation and risk management, and environmental protection and resource efficiency;
- write successful bids into EU and other research grant schemes;
- develop and enhance network of collaborators across the European Union;
- form partnerships between the participating organisations, that outlast the project.

Whilst the project focuses on supporting HGI-CGS to achieve a step-change in its research capacity, and the research profile of its scientists, it also offers significant benefits to GEUS and BGS-UKRI. By exposing GEUS and BGS-UKRI staff to a diverse range of geological settings within Croatia, particular environmental challenges, and to a different, large group of stakeholders, partnering institutions will also increase their level of expertise and knowledge.

Acknowledgements

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Keywords: Horizon 2020, HGI-CGS, GEUS, BGS-UKRI, training

Monitoring of Rakovac Spring Discharge Using Rectangular Sharp-Crested Weir, Mt. Žumberačka Gora

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The subject of the research is spring Rakovac, located on the Mt. Žumberačka gora in the Poklek area, about 1.5 km northwest of the village Koretići (Fig. 1). Research has been carried out to determine the possibility of water usage from the spring Rakovac as an additional source of drinking water for the needs of the public water supply of the City of Samobor. One of the main goals of the research was to determine the discharge of the spring Rakovac. For achieving this goal, a rectangular sharp-crested weir was built directly downstream from the spring, allowing monitoring of discharge i.e. flowrate at two-hour intervals. Considering the geometry of the stream Rakovac, the weir was constructed as a concrete structure, with the crest and lateral sides of the weir coated with inox stainless steel plates (Fig. 2). The

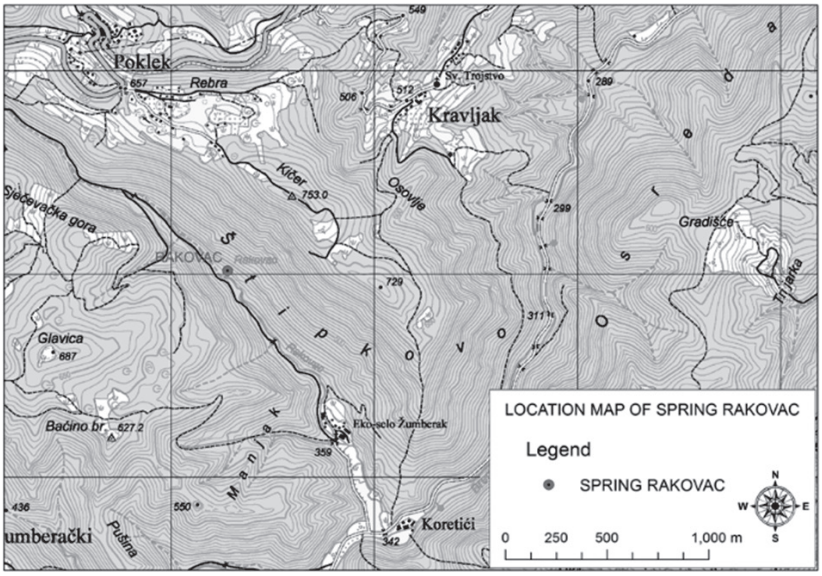

Figure 1. Location map of spring Rakovac.

weir was designed based on the geometry of the stream Rakovac and the expected maximum spring discharge. After its construction, a metallic pipe with a lid and a lock was installed, and automatic pressure gauges (loggers) were installed inside the pipe. The absolute pressure measured at two-hour intervals was converted to stream overflow height and barometric compensation was performed using atmospheric pressure measurement data. The weir was equipped with a stream gauge, necessary for measurements of the reference height of the stream overflow. In addition to the stream gauge, a metal plate with a flowrate curve was installed, enabling on-site determination of the flowrate. The weir was put into operation on November 15, 2018 and the measurements started on the same day at 16:00 hours.

Figure 2. Weir Rakovac.

Within the research of the spring Rakovac, monitoring of the flowrate will be conducted by the end of 2019. Analysis of time series obtained during the period of measurement will include analyses of the flowrate duration and frequency and the recession of the hydrograph. Further, analysis of correlation, cross correlation and regression of precipitation and spring discharge as well as analysis of biological minimum of the Rakovac stream flowrate will be performed, which will enable determination of available water quantities at the spring Rakovac potentially used for the needs of the public water supply of the City of Samobor.

Keywords: spring Rakovac, Mt. Žumberačka Gora, discharge, rectangular weir, flowrate

The Establishment of a Teaching-Research Polygon in the Area of Velika Gorica Well Field, Zagreb Aquifer

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Groundwater reserves of the Zagreb unconfined aquifer are defined as a strategic resource of groundwater in Croatia within the Croatian Waters' Water Management Strategy. They present the only source of potable water for the inhabitants of the City of Zagreb and one part of the Zagreb County. In the past decades, groundwater level decline have been identified in the Zagreb aquifer (NAKIĆ et al., 2013). Consequently, it became important to identify and quantify every single source of its recharge. The research presented within this abstract is focused on one part of the aquifer recharge i.e. the recharge which occurs from precipitation and infiltrates through the soil and the unsaturated zone into the aquifer (RUŽIČIĆ et al., 2016).

For the purpose of this research, a teaching-research polygon was constructed in order to observe and measure the process of precipitation infiltration through the soil and the unsaturated zone. Polygon is located in the southern part of the Zagreb aquifer, in the Eutric Cambisol on Holocene deposits (BOGUNOVIĆ et al., 1996), at the Velika Gorica well field. Teaching-research polygon is designed as a pedological pit with glass walls installed on two sides, enabling insight into the soil and unsaturated zone profile. Probes and suction cups are installed at different depths, with respect to defined pedological horizons. Probes measure moisture content, electrical conductivity and temperature, while suction cups are used to collect water that infiltrates into the unsaturated zone. Teaching-research polygon also has a weather station and pluviometer installed on the surface.

Future monitoring will include measurement of major ion concentrations and stable isotope composition of water sampled from unsaturated zone, groundwater and precipitation. Ionic composition will be determined using ion chromatography while the water stable isotopes will be determined by laser absorption spectroscopy. By continuous measurement of selected parameters and frequent sampling of infiltrated water, it will be possible to quantify the value of effective infiltration and to determine the main geochemical processes that are occurring in the unsaturated zone. In order to better understand the water flow through the unsaturated zone, numerical simulation of water dynamics will be performed using HYDRUS-1D (ŠIMUNEK et al., 2008), while 2D and 3D images of moisture distribution will be obtained by using MoisturEC program (TERRY et al., 2018).

Keywords: unsaturated zone, pedological pit, effective infiltration, Velika Gorica well field, Zagreb aquifer

References

BOGUNOVIĆ, M., VIDAČEK, Ž., RACZ, Z., HUSNJAK, S. & SRAKA, M. (1996): Namjenska pedološka karta Republike Hrvatske u mjerilu 1:300.000 (Soil suitability map for cultivation of the Republic of Croatia, 1:300000). Zavod za pedologiju Agronomskog fakulteta Sveučilišta u Zagrebu.

NAKIĆ, Z., RUŽIČIĆ, S., POSAVEC, K., MILEUSNIĆ, M., PARLOV, J., BAČANI, A. & DURN, G. (2013): Conceptual model for groundwater status and risk assessment - Case study of the Zagreb aquifer system. Geologia Croatica, 66, 55-77.

RUŽIČIĆ, S., MILEUSNIĆ, M., POSAVEC, K., NAKIĆ, Z., DURN, G. & FILIPOVIĆ, V. (2016.): Water flow and solute transport model of potentially toxic elements through unsaturated zone at regional well field Kosnica. Hydrological processes, 30, 4113-4124.

ŠIMUNEK, J., VAN GENUCHTEN, M.TH. & ŠEJNA, M. (2008): Development and applications of the HYDRUS and STANMOD software packages, and related codes. Vadose Zone Journal, 7, 587-600.

TERRY, N., DAY-LEWIS, F.D., WERKEMA, D. & LANE JR, J.W. (2018): MoisturEC: A New R Program for Moisture Content Estimation from Electrical Conductivity Data. Groundwater, Vol 56, No. 5, 823-831.

The Panicherevo Molybdenum Deposit, Bulgaria: Sulfur Isotope Results and Implications for Ore Genesis

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The Panicherevo deposit is located in the Eastern Sarnena Sredna Gora mountain, Bulgaria. It is hosted in the granites of the Kazan pluton and partly in the rocks of the Pirdop gneiss complex. Main ore minerals are molybdenite, pyrite, chalcopyrite and less common galena, sphalerite, rutile, magnetite, hematite, fahlore (STAYCOV, 1963; TODOROV, 1985; RACHEVA, 2018). The deposit was prospected in the last several years (MANKOV et al., 2017, unpublished).

Sulfur isotope compositions were analyzed in 6 molybdenite and in 8 pyrite samples from 6 drill holes and 2 prospecting mines.

The $\delta^{34}S$ values of molybdenite vary in a narrow range from +2.18 to +4.49 ‰ with mean value of 3.38 ‰. These results indicate that the sulfur is mainly derived from a homogeneous magmatic source (ROLLINSON, 1993).

By contrast, the $\delta^{34}S$ values of pyrite range from –10.96 ‰ to +5.03 ‰ with mean value of –0.10 ‰. These results can be divided in 2 groups: 1) from –10.96 ‰ to –10.81 ‰ and 2) from +2.65 ‰ to +5.03 ‰. This variety in the $\delta^{34}S$ values suggest that part of pyrite mineralisation originates from mantle-derived sulfur (positive $\delta^{34}S$ values). The negative $\delta^{34}S$ values are likely influenced by either sulfur isotope fractionation processes or input of sulfur with different isotope compositions during their formation. Similar negative $\delta^{34}S$ values of pyrite from other deposits were previously interpreted to have resulted from relatively oxidized fluids (ZHANG, 1989) or a probable secondary pyrite deposition (KIM et al., 2019).

Further analyses on fluid inclusions studies on quartz, salinity as well as isotopes of carbon from post-ore calcite veins will be conducted providing more information about the genesis of ore fluids.

Keywords: *molybdenite, pyrite, sulfur isotopes, molybdenum, Panicherevo*

References

KIM, Y., LEE, I., OYUNGEREL, S., JARGAL, L. & TSEDENBAL, T. (2019): Cu and S isotopic signatures of the Erdenetiin Ovoo porphyry Cu-Mo deposit, northern Mongolia: Implications for their origin and mineral exploration. Ore Geology Reviews, 104, 656-669.

MANKOV, S., ANTONOV M., MIHAYLOV, G., VANCHEV, P., VOLOBAYEV, I., GOSPODINOVA, E., RUSKOV, K., STEFANOVA, E., KOMANSKA, M., TSVETANOVA, L. & RACHEVA, D. (2017): Geological report on the research and exploration works carried out in the Kohouk Dere area of Demir Boklu, located in the village of Bratya Kunchevi, Stara Zagora district, the villages of Elhovo and Edrevo, Nikolaevo district and the village of Panicherevo, Gurkovo region, Stara Zagora district, with the calculation of stocks and resources of molybdenum raw material as of 30.06.2017. (in 10 volumes; in Bulgarian), Unpubl. Geol. Report, Geofund, Ministry of Energy.

RACHEVA, D., MLADENOVA, V. & DIMITROVA, D. (2018): LA-ICP-MS of molybdenite from the Panicherevo deposit, Sarnena Sredna Gora mountain, Bulgaria. Review of the Bulgarian Geological Society, vol. 79, part 3, 2018, 27-28. National Conference with international participation "GEOSCIENCES 2018".

ROLLINSON, H.R. (1989): Using Geochemical Data: Evaluation, Presentation, Interpretation. Longman Group Limited, 303-315.

STAYCOV, M. (1963): Les minerais de molybdène aux environs du village Dolno-Panitcherevo arrondissement de Stara Zagora. Annuaire de la direction generale de geologie, volume XIV, 57-80 (in Bulgarian with French abstract).

TODOROV, T. & STAYKOV, M. (1985): Rhenium content in molybdenite from ore mineralizations in Bulgaria. Geologica Balcanica, 15, 6, Sofia, Decemb., 1985, 45-58.

ZHANG, L.G. (1989): Petrogenetic and Minerogenetic Theories and Prospecting. Press of Beijing University of Technology, Beijing, 200 p. (in Chinese).

Mineralogical and Geochemical Characteristics of Quaternary Pelitic Sediments From Grmoščica (Zagreb) Abandoned Clay Pit

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Two outcrops (GRMOŠČICA-I 17.5m and GRMOŠČICA-II 10.4m) were studied in the area of Zagreb during the mapping of the Basic Geological Map of the Republic of Croatia 1:50 000 twenty years ago. Sediments from outcrops are composed of clay, silt, sand and gravel. They belong to the Pontian and Quaternary, informal lithostratigraphic Formations Andraševac and Bistra (AVANIĆ,1997, KOVAČIĆ,1998). In this paper, five samples of sedimentary rocks, which belong to Bistra Formation, from sample storage of the Croatian geological Survey, were investigated. According to AVANIĆ (1997), clay, sand and silt facies are present, which are typical for alluvial environments of floodplains. The aim of this research was to determine quantitative mineralogical composition and provenance of the analysed samples.

Mineralogical analysis included X-ray powder diffraction (XRPD) analysis that was made on random mounts of bulk samples, and oriented mounts of <63 μm and <2 μm fraction. Oriented mounts were recorded after following treatments: a) air drying, b) saturation with K^+ and Mg^{2+}, c) ethylene-glycol solvation, d) DMSO solvation, e) glycerol solvation, f) heating to 300 °C, 400 °C and 550 °C.

These bulk samples consist of quartz, illite/muscovite and swelling clays. Calcite is present in three samples from outcrop GRMOŠČICA-II. Quartz, illite/muscovite, smectite and kaolinite were identified within the oriented mounts of the <63 μm and <2 μm fraction, while chlorite and vermiculite were present in some samples only. Quartz is the most abundant mineral in <63 μm fraction, while <2 μm fraction is rich in clay minerals.

The carbonate content determined by Schibler calcimeter in samples GRM 2-1, GRM 2-2 and GRM 2-3 from GRMOŠČICA-II outcrop was 2.5%, 6.1% and 20.2% respectively.

The granulometric analysis was made by Laser Diffraction Particle Size Analyzer on <63 μm fracton separated by wet sieving method. Silt fraction dominates all samples, but samples from GRMOŠČICA-I outcrop were determined as clayey sandy silt, while samples from GRMOŠČICA-II outcrop were described as sandy clayey silt.

Geochemical analysis was made at ACME Laboratory (Canada) using ICP-ES method for main elements determination, and ICP-MS method for REE and trace elements determination. These geochemical data was used to determine provenance and *CIA* (*Chemical Index of Alteration*) and *ICV* (*Index of Compositional Variability*) (CULLERS & PODKOVYROV, 2002). Weight percentage (wt%) of Al_2O_3–(CaO*+Na_2O)–K_2O and La-Th-Sc were plotted in triangular diagrams and La/Sc-Th/Co scatter plot in order to distinguish chemical weathering and source rock composition (CULLERS & PODKOVYROV, 2000). These results accompanied by *CIA* and *ICV* implied that the source rocks originate from different types of rocks, predominantly from acidic, quartz enriched rocks.

Keywords: *Quaternary, clay minerals, X-ray diffraction, chemical composition, provenance*

References

AVANIĆ, R. (1997): Litostratigrafski stup Grmoščica-II, Projekt: Geološka karta Republike Hrvatske 1:50.000. Institut za geološka istraživanja, Zavod za geologiju.

CULLERS, R.L. & PODKOVYROV, V.N. (2000): Geochemistry of the Mesoproterozoic Lakhanda shales insoutheastern Yakutia, Russia: implications for mineralogical and provenance control, and recycling. Elsevier, Precambrian Research, 104, 77-93.

CULLERS, R.L. & PODKOVYROV, V.N. (2002): The source and origin of terrigenous sedimentary rocks in the Mesoproterozoic Ui group, southeastern Russia. Elsevier, Precambrian Research, 117, 157-183.

KOVAČIĆ, M. (1998): Sedimentno - petrografske analize uzoraka s geološkog profila Grmoščica-I. Projekt: Geološka karta Republike Hrvatske 1:50.000. Institut za geološka istraživanja, Zavod za geologiju.

Subaerial Exposure Surfaces Within Early Cretaceous Carbonate Deposits of Selina Quarry, Istria

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The Istrian peninsula, the north-western part of the former Adriatic Carbonate platform (AdCP), represents a region with well-preserved stratigraphic records that offer important insights into the significant events of the AdCP geological history. The Istrian succession is mainly composed of shallow water carbonates accumulated from the late Middle Jurassic to Eocene, and in a lesser extent of Eocene carbonate and clastic rocks, and Quaternary terra rossa and loess deposits. This succession can be divided into four sedimentary units or megasequences of carbonate deposits bounded by important discontinuities – emersion surfaces with different durations.

The object of this study are two subaerial exposure surfaces within the 27 m thick Lower Cretaceous succession (Upper Barremian–Upper Albian) in Selina Quarry, near Sveti Lovreč. The purposes were to determine the composition and the provenance of the clay sediment and describe depositional environments. Additionally, micropaleontological/microfacies analyses of carbonate rocks were performed on samples taken from the bottom and top of the subaerial exposure surfaces to determine the age and duration of the subaerial exposures.

Mineralogical X-Ray powder diffraction analyses revealed that mixed layered illite-smectite (I-S), illite and smectite are the main constituents of clay sediment, which is at the sampling place up to 1.4 m thick, found at the older subaerial exposure surface. The content of illite increases upwards as well the illite content of I-S. In its lower part I-S contains 30–40% illite component while in the higher part of clay sediment illite content in I-S is ~70%. Other determined minerals are calcite and potassium feldspar. The modal optical analysis of the heavy mineral fraction revealed the presence of opaque minerals (pyrite, marcasite and goethite) and titanite, zircon, tourmaline, garnet, biotite, epidote, while in the light fraction calcite, dolomite and muscovite were found. Sediment at the younger subaerial exposure surface, beside clay minerals (dominant illite and minor illite rich I-S), contains gypsum, jarosite and traces of potassium feldspar. It is possible that those minerals are deposited during oscillating transgression or in the main emersion phase. Considering the isolation of the AdCP during subaerial exposure surfaces (Aptian/Albian and Albian), the source of the material could be volcanic, aeolian or insoluble limestone residue (resedimented). Based on the dominance of illite and illite-smectite over smectite, it could be assumed that at least part of the material had volcanic origin, which was first altered to smectite and later by paedogenesis/diagenesis to I-S and illite.

Microfacies analyses of samples from this locality represent various shallow water carbonate platform microfacies types. Determination of stratigraphic position of the investigated Late Barremian–Late Albian succession was based on the identification of microfossil assemblages (benthic foraminifera and calcareous algae *Dasycladales*) and used their taxa as index fossils.

Considering the obtained results, the first subaerial exposure surface is recognized as the Late Aptian–Early Albian regional exposure, while the second one is formed during oscillating transgression in the Late Albian.

Keywords: *subaerial exposure surface, Early Cretaceous (Late Barremian–Late Albian), clay sediments, Selina Quarry, Istria*

Application of Rift Sequence Stratigraphy in Seismic Interpretation of the Lower and Middle Miocene Rocks in Eastern Part of the Drava Depression

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Formation of the Lower and Middle Miocene rocks in Eastern part of the Drava Depression, as well as in the entire North Croatian Basin, is associated with rifting processes and sedimentary infill of the depocenters created during the syn-rift tectonic phase. Surface outcrops of Lower Miocene succession consist of alluvial sandstones and conglomerates, while Middle Miocene sediments are composed of Lithothamnion limestone's to marls, indicating sedimentation in shallow marine environment. Core samples from exploration wells differ in lithology - from rockfall breccia and debris conglomerates to both shallow and deeper marine sediments of various lithology. Syn-rift sedimentation usually comprises Miocene volcanic rocks confirmed both in on outcrops and from the well data.

Seismic 3D data and interpreted seismic facies suggest that identified lithologies of Lower and Middle Miocene could be spaciously linked. Rift sequence stratigraphic approach (PROSSER, 1993) defines tectono-stratigraphic units, which are associated with cogenetic fault activity during the syn-rift phase. The syn-rift tectonic phase units are primarily detected by tilting of reflexes in the hanging wall units and by other seismic facies characteristic that are specific for the syn-rift sedimentation. This is how the pre-rift, syn-rift and post-rift, main tectono-stratigraphic units were interpreted and mapped in this study. In thicker portions of Lower and Middle Miocene successions, the rift sequence architecture can also be studied by interpretation of smaller units – system tracts.

Interpreted seismic data pinpoint to cogenetic formation of depocenters as a result of extensional reactivation of the pre-Neogene WNW-ESE striking faulted structures that happened during Lower and Middle Miocene. Syn-rift depocenters were formed either directly in the hanging wall of these reactivated faults or along newly formed normal faults that were structurally predefined by the older pre-Neogene faulted structures. Pre-rift units are usually overlain with initial rift system tract, i.e., the basal seismic facies defined on seismic sections. The initial rift system tract can be distinguished in the thickest portions of the Lower and Middle Miocene strata as onlaping or downlaping on the pre-rift units. Main syn-rift system tract is characterized by: 1) significant vertical offsets along normal faults, 2) tilting of the hanging wall blocks, and 3) seismic facies of marginal fan-aprons. In marginal areas of the syn-rift depocenters only a portion of the main syn-rift system tract can present entire syn-rift succession. In the same time, the well data indicate that initial and main syn-rift system tracts comprise of the entire Lower Miocene and part of the Middle Miocene sediments. Immediate post-rift system tract is characterized by cessation of normal fault activity, onlap on the syn-rift sediments and marked paleo-structures as well as by continuous seismic facies. Immediate post-rift system tract is composed of the upper portion of the Middle Miocene together with the lowermost Pannonian sediments. In the study area, the late post-rift system tract represents the Lake Pannon infill, excluding its lowermost portion.

This study suggests that the rift sequence seismo-stratigraphic analyses provides the basis for delineation of principal tectono-stratigraphic units, which can give an additional information on the evolution of the rift basin in Drava Depression. In regions with significant thickness of these rock units in the deep subsurface, this methodology can be used for mapping of the Lower and Middle Miocene rock units in more detail. In this way achieved results can also facilitate the spatial correlation of the Lower and Middle Miocene rocks regionally.

Keywords: *Drava depression, Miocene, syn-rift, rift sequence stratigraphy, seismic interpretation*

References

PROSSER, S. (1993): Rift-related linked depositional systems and their seismic expression. Geological Society Special Publication, 71, 35-66.

3D Seismic Characterization of Upper Miocene Deposits (Drava TROUGH)

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The entire Drava trough covers the surface area of about 12 000 square km, where approximately 9100 belong to the Croatia (MALVIĆ & CVETKOVIĆ, 2013). The Drava trough with the thickness of Neogene sequence up to 7000 m holds Upper Miocene gas-bearing progradational succession that still represents potential regarding new gas plays related to anomalous seismic amplitude record. Regional deposition at the time of Pannonian age indicates the beginning of significant changes in the environment of Croatian part of the Pannonian Basin System (CPBS), with a distinct domination of turbidities. Following upper Miocene coarsening-upward succession, which reflects the infilling style, the progradation of clastic systems into the brackish lake is traced in the Drava trough from NNW direction towards SE.

The aim of this study was to characterize seismic anomalies and define sedimentary bodies within the 3D seismic volumes of Drava Depression in the Upper Miocene stratigraphic sequence. Progress in characterization of hydrocarbon bearing reservoirs is enabled by analysis of pre-stack and post-stack seismic attributes. Furthermore, it was useful in mapping of sand bodies and allowed to define facies changes, discordance, faults and stratigraphic relations.

Attribute analysis includes structural and amplitude attributes. In some areas, amplitude versus offset (AVO) analysis has been applied. AVO is a seismic method that analyzes the variation in seismic reflection amplitude with offset that indicates differences in lithology and fluid content in rocks above and below the reflector. A gas-filled reservoirs might show increasing amplitude with offset, whereas coal or water-saturated reservoirs might show decreasing amplitude and it is successfully used in hydrocarbon explorations.

By applying the spectral decomposition method, a better image of the geological bodies and the distribution of facies in the space were obtained. Seismic spectral decomposition is a powerful analysis tool used to characterize the frequency content of seismic data. It is used to study attenuation effects caused by hydrocarbons.

By analyzing the seismic attributes lateral distribution of reservoir sediments were defined more precisely, with respect to the lithological variations of sedimentary bodies and the main depositional direction.

Keywords: *Drava Trough, Seismic attributes, Upper Miocene, Croatia*

References

MALVIĆ, T. & CVETKOVIĆ, M. (2013): Lithostratigraphic units in the Drava Depression (Croatian and Hungarian parts) – a correlation, Nafta, 64 (1), 27-33.

Cretaceous Alkali Magmatism Within Slavonian Mts. (Mts. Požeška Gora and Papuk)

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Progressive closure of the Neotethys Ocean followed by the intra-oceanic subduction in the Jurassic, finally ended with the Late Cretaceous – Paleogene continent-continent collision between tectonic Tisia Mega-Unit (part of the European plate) as the upper plate and Inner Dinnarides (Adria microplate) as the subducting plate (SCHMID et al., 2008). This collision formed a large suture zone named Sava (-Vardar) Zone (PAMIĆ, 2002); a belt with different type of rocks that bare evidences of this geodynamic event(s). Among them, rocks investigated in this study are rhyolite from the Rupnica locality (Voćin) and red granite from Mt. Požeška Gora (Gradski Vrhovci). The former one is also known for the well exposed phenomenon of columnar jointing which is interpreted as a consequence of a rapid cooling (BALEN & PETRINEC, 2014). The rocks from this two localities, although presently 35 km apart, have similar geochemical characteristics and contemporaneous ages, suggesting the same source of alkali magmatism, as it was previously proposed by PAMIĆ (1987), PAMIĆ & LANPHERE (1992) and PAMIĆ et al. (2000).

Rupnica rhyolite is mainly composed of albite and quartz with minor clinopyroxene and amphibole. Zircon, apatite, anatase and Fe-oxides are accessory phases. Mt. Požeška gora granite is mainly composed of alkali feldspar (perthite) and quartz with minor albite. Hematite (responsible for the rock colour), zircon, apatite and monazite are accessory phases. Both rocks have highly-siliceous composition (66-76 wt.% SiO_2), are enriched in alkalies (8.1–9.2 wt.% K_2O+Na_2O, high-K calc-alkaline series) and classify as an alkali rhyolite i.e. alkali granite. They both belong to a group of peraluminous, oxidized and ferroan rocks with low CaO, MgO, MnO and FeO_T contents, but with high $FeO_T/(FeO_T+MgO)$ ratios (MI=0.87–0.98), which is similar to magmas derived from the lower crust and are typical for an A-type of granitic rocks (WHALEN et al., 1987). Some specific elemental concentrations combined with specific elemental ratios (such as K/Ba, K/Rb, Rb/Sr, Zr/Hf and Th/U) and zircon geochemistry imply crustal but also mantle signature in the melt, where rhyolite might have had a slightly more mantle contribution than the granite.

The investigation of zircon morphology after PUPIN (1980) resulted in the dominance of the G_1-type for the rhyolite and D-type for the granite. Both types are ascribed to an alkali and dry A-type of magma with the origin in the lower crust or even upper mantle, where G_1-type is characteristic for somewhat lower temperatures compared to D-type. Calculated Zr-saturation temperatures are high for both rocks (840–870 °C for rhyolite; 860–950 °C for granite) compatible with rhyolite high Ti-in-zircon and apatite saturation temperatures (930 °C and 900 °C, respectively).

Geochemical discrimination diagrams place the investigated rocks into a within-plate setting and to a lesser extent to a volcanic arc setting as a post-collision rhyolite/granite. Moreover, Rupnica rhyolite and Mt. Požeška Gora granite both show the geochemical signature of an A_2-type (EBY, 1992), derived by melting of subcontinental lithosphere or lower continental crust with or without mantle input. This type of rocks can be found in the post-collisional i.e. post-orogenic settings, originally formed by subduction or continent-continent collision.

Zircon ages of Rupnica rhyolite obtained with LA-ICP-MS and determined from $^{206}Pb/^{238}U$, $^{207}Pb/^{235}U$ and $^{208}Pb/^{232}Th$ ratios are 81.2±1.0, 82.9±0.9 and 81.6±0.9 Ma, respectively. Those ages are contemporaneous with the recently determined zircon ages from Mt. Požeška Gora granite, which are 85.9±1.4, 86.3±1.0 and 86.1±0.8, respectively (BALEN et al., in review). Studied igneous rocks therefore indicate the local transition from compressional to extensional tectonic regime at about 86–82 Ma.

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Keywords: *alkali magmatism, extension, Cretaceous, zircon, Europe-Adria collision*

References

BALEN, D. & PETRINEC, Z. (2014): Development of columnar jointing in albite rhyolite in a rapidly cooling volcanic environment (Rupnica, Papuk Geopark, Croatia). Terra Nova, 26, 102–110.

BALEN, D., SCHNEIDER, P., MASSONE, H.-J., OPITZ, J., LUPTÁKOVÁ, J., PUTIŠ, M. & PETRINEC, Z. (in review): Evolution of the Late Cretaceous A-type granite from Mt. Požeška Gora (N Croatia) with geodynamic clues to the Western Neotethys closure along the Europe-Adria suture zone. Mineralogy and Petrology.

EBY, G.N. (1992): Chemical subdivision of the A-type granitoids: petrogenetic and tectonic implications. Geology, 20, 641-644.

PAMIĆ, J. (1987): Mladoalpinski alkalijsko-feldspatski graniti (aljaskiti) Požeške gore u Slavoniji. Geologija Ljubljana, 30, 183-205.

PAMIĆ, J. & LANPHERE, M. (1992): Alpine A-type granites from the collisional area of the northernmost Dinarides and Pannonian Basin, Yugoslavia. Neues Jahrbuch für Mineralogie, Abhandlungen, 162, 215-236.

PAMIĆ, J., BELAK, M., BULLEN, T.D., LANPHERE, M.A. & McKEE, E.H. (2000): Geochemistry and geodynamics of a Late Cretaceous bimodal volcanic association from the southern part of the Pannonian Basin in Slavonija (northern Croatia). Mineralogy and Petrology, 68, 271-296.

PAMIĆ, J. (2002): The Sava-Vardar Zone of the Dinarides and Hellenides versus the Vardar Ocean. Eclogae Geologicae Helvetiae, 95, 99–113.

PUPIN, J.P. (1980): Zircon and granite petrology. Contributions to Mineralog and Petrology, 73, 207-220.

SCHMID, S.M., BERNOULLI, D., FÜGENSCHUH, B., MATENCO, L., SCHEFER, S., SCHUSTER, R., TISCHLER, M. & USTASZEWSKI, K. (2008): The Alps-Carpathians-Dinarides connection: a compilation of tectonic units. Swiss Journal of Geosciences, 101, 139-183.

WHALEN, J.B., CURRIE, K.L. & CHAPPELL, B.W. (1987): A-type granites: geochemical characteristics, discrimination and petrogenesis. Contributions to Mineralogy and Petrology, 95, 407-419.

Rockfall Susceptibility Assessment at the Slope Scale

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The aim of this paper is to present a method for rockfall susceptibility assessment at the slope scale, which is based on automated spatial kinematic analysis and calculation of the Kinematic Hazard Index. Rockfall susceptibility is defined as the likelihood of a rockfall occurring in an area based on local terrain conditions (BRABB, 1984). Investigation of rockfall susceptibility at the slope scale is based on the analysis of the relation between discontinuities and slope morphology (MATASCI et al., 2017), that can indicate if a certain instability mechanism is possible at a specific location on the rock slope. Method for rockfall susceptibility assessment at the slope scale presented in this paper is a follow-up of the researches presented in SEČANJ et al. (2017, 2018 and 2019). The method was tested at the locations of different size and complexity: rock cuts along the road in the Krka National Park, rock cuts above parking plateau in Matulji Municipality and slopes with complex morphology above the Town of Omiš.

In order to gather input data for susceptibility assessment, remote sensing techniques were employed to rapidly obtain orientation of rock faces, including in the field inaccessible areas. Discontinuity data was obtained from the high-resolution point clouds and 3D models using different techniques and software. Possible rockfall sources can be identified by 3D spatial kinematic analysis that analyse kinematic possibility of specific instability mechanism defined by the geometry of the slope and discontinuities. The input parameters for the 3D spatial kinematic analysis are: 1) quasi-homogenous engineering geological zones (EGZ), defined by rock mass properties, representative discontinuity sets and the geometrical properties of the slope, 2) the orientation of the slope (dip angle and dip direction obtained from the digital surface model), 3) orientations of the discontinuities (obtained from the point cloud in the Split-FX and CloudCompare software), and 4) the average value of discontinuity friction angle. Spatial kinematic analysis was performed for each polygon of the digital surface model for all instability mechanisms (plane and wedge failure, flexural and block toppling). Kinematic Hazard Index (KHI) defined by CASAGLI & PINI (1993) is calculated for each model polygon where one or more modes of failures are possible. KHI is defined as relative ratio between number of discontinuities and number of intersections on which failure can occur in relation to the total number of discontinuities and intersections in one EGZ. Spatial kinematic analysis and the calculation of the KHI are automated with the in-house MATLAB scripts and functions

using vector analysis for each polygon of high-resolution 3D digital model. Results are maximal values of Kinematic Hazard Index (MKHI) for each polygon. Interpolated values of MKHI represent rockfall susceptibility map or 3D model where the probability of instabilities is expressed by the colour scale, varying from green to red as the MKHI increases. Verification of the analysis was performed by comparison of areas with high susceptibility with realistic point cloud model depicting rock slope morphology and potentially unstable rock blocks.

The method for rockfall susceptibility assessment, presented in the paper, has proven that it can be used for different types of rock slopes, ranging from single rock cuts to the area of complex morphology with multiple slopes of different orientation. Resulting rockfall susceptibility maps and 3D models are a useful tool in preliminary rock fall hazard assessment, because high susceptible areas indicate possible rockfall sources that require detailed engineering geological and geotechnical investigations. The applied method enables more objective selection of the slope parts for following up slope stability analysis and rockfall simulations (ARBANAS et al., 2019). Besides advantages related to fast assessment of rock slope instability, there are also some limitations in the presented approach. The analysis is based on heuristically determined average value of discontinuity friction angle which may led to overestimation or underestimation of the KHI values in certain parts of the slope. Despite this, rockfall susceptibility assessment provides useful input data for rockfall hazard assessment and deterministic rock slope stability analyses. Considering geological setting and extent of Dinarides in Croatia (MIHALIĆ ARBANAS et al., 2017) there is potentially large area of possible application of the presented method for rockfall susceptibility assessment, as a tool for risk reduction together with engineering measures of rock slope protection.

Keywords: *rockfall susceptibility, spatial kinematic analysis, Kinematic Hazard Index, slope scale*

References

ARBANAS, Ž., VIVODA PRODAN, M., DUGONJIĆ JOVANČEVIĆ, S., PERANIĆ, J., UDOVIČ, D., BERNAT GAZIBARA, S., KRKAČ, M., SEČANJ, M. & MIHALIĆ ARBANAS, S. (2019): Rockfall Modelling and Rockfall Protection at the Slopes above the City of Omiš, Croatia. In: SOKOLIĆ, I., MIŠČEVIĆ, P., ŠTAMBUK CVITANOVIĆ, N. & VLASTELICA, G. (eds.): Geotechnical challenges in karst, Omiš, Croatia, April. 11-13, 2019. Hrvatsko geotehničko društvo, Split, 121-126

BRABB, E. (1984): Innovative Approaches for Landslide Hazard Evaluation. IV International Symposium on Landslides, Toronto, 307-323.

CASAGLI, N. & PINI, G. (1993): Analisi cinematica della stabilità in versanti naturali e fronti di scavo in roccia. In: Proceedings 3° Convegno Nazionale dei Giovani Ricercatori in Geologia Applicata, Oct. 28-30, 1993. Potenza, Italy. 223-232.

MATASCI, B., STOCK, G.M., JABOYEDOFF, M., CARREA, D., COLLINS, B.D., GUÉRIN, A., MATASCI, G. & RAVANEL, L. (2017): Assessing rockfall susceptibility in steep and overhanging slopes using three-dimensional analysis of failure mechanisms. Landslides: 1-20.

MIHALIĆ ARBANAS, S., SEČANJ, M., BERNAT GAZIBARA, S., KRKAČ, M. et al. (2017): Landslides in the Dinarides and Pannonian Basin – from the largest historical and recent landslides in Croatia to catastrophic landslides caused by Cyclone Tamara (2014) in Bosnia and Herzegovina. Landslides, 14, 6, 1861-1876.

SEČANJ, M., MIHALIĆ ARBANAS, S., KORDIĆ, B., KRKAČ, M. & BERNAT GAZIBARA, S. (2017): Identification of Rock Fall Prone Areas on the Steep Slopes Above the Town of Omiš, Croatia. In: MIKOŠ, M., VILIMEK, V., YIN, Y. & SASSA, K. (eds): Advancing Culture of Living with Landslides. Springer, 2017. 481-487.

SEČANJ, M., BERNAT GAZIBARA, S., MIHALIĆ ARBANAS, S., KRKAČ, M., MARTINKO, M. & ARBANAS, Ž. (2018): Identification of potentially unstable rock blocks on the road cut in the Krka National park, Croatia. In: JEMEC AUFLIČ, M., MIKOŠ, M. & VERBOVŠEK, T. (eds): Advances in Landslide Research - Proceedings of the 3rd Regional Symposium on Landslides in the Adriatic Balkan Region, Ljubljana, Slovenia, Oct. 11-13, 2017. Geological Survey of Slovenia, Ljubljana, 113-118.

SEČANJ, M., MIHALIĆ ARBANAS, S., KRKAČ, M., BERNAT GAZIBARA, S. & ARBANAS, Ž. (2019): Preliminary rockfall susceptibility assessment of the rock slopes above the Town of Omiš (Croatia). In: SOKOLIĆ, I., MIŠČEVIĆ, P., ŠTAMBUK CVITANOVIĆ, N. & VLASTELICA, G. (eds.): Geotechnical challenges in karst, Omiš, Croatia, April. 11-13, 2019. Hrvatsko geotehničko društvo, Split, 347-352.

Mineralogical and Petrological Characteristics of Middle Triassic Volcanic and Pyroclastic Rocks from the Kuna Gora Mtn. (NW Croatia)

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Along the northern slopes of Kuna Gora Mtn., situated in the junction area of the three major geodynamic units – southern Alps, the Dinarides, and Tisza, the outcrops of volcanic and volcanoclastic rocks associated with middle Triassic carbonates are reported. This area belongs to the south-western part of the Zagorje-Mid-Transdanubian Shear Zone (PAMIĆ & TOMLJENOVIĆ, 1998). The surface manifestations of volcanic and associated pyroclastic rocks are relatively modest totalling about 0.3 km^2. Preliminary results on petrography, mineral chemistry and bulk rock chemical composition of these rocks are provided in this contribution. Furthermore, K-Ar age on the K-feldspar mineral separate from basalts is also determined. Their K-Ar age is 241.1±5.2 Ma, which in the geological time scale of OGG et al. (2016) corresponds to late Anisian-early Ladinian.

Analysed volcanites occur in the form of massive lavas and are interstratified with minor layers of vitro-crystalloclastic tuffs. They are of porphyritic texture and homogenous structure and are dominantly consisted of homogenous to slightly sericitized K-feldspar ($An_{0.0}Ab_{1.1\text{-}3.7}Or_{96.3\text{-}98.9}$), while albitized plagioclase ($An_{0.21\text{-}0.67}$) and clinopyroxene (augite; $Wo_{43.5\text{-}44.9}En_{43.5\text{-}43.9}Fs_{7.3\text{-}11.2.}$) are rarely encountered. Minor phases are chlorite, Ti-bearing magnetite (TiO_2 = 15.58 wt%; FeO = 74.08 wt%), Fe-bearing Ti-oxide (rutile?; TiO_2 = 98.12 wt.%), ilmenite, hematite and illite. In pyroclastic rocks major crystaloclast is K-feldspar (sanidine; $An_{0.0}Ab_{1.0\text{-}3.2}Or_{96.5\text{-}98.7}$). Volcanic rock microcrystalline matrix is holocrystalline or, alternatively, can be made of devitrified volcanic glass. The latter is the dominant component of the matrix of pyroclastic rocks. Millimetre-scale vesicules are often filled by flaky chlorite.

Chemical composition of volcanic and pyroclastic rocks is characterized by high amounts of K (K_2O = 8.36-9.58 wt%), low Na (Na_2O = 0.13-0.81 wt.%), and Ti (TiO_2 = 0.91-0.96 wt.%), while silica varies between 48.40 and 50.29 wt.%. High K content is explained by elevated modal abundances of K-feldspar (~55-60%). The loss of ignition value is between 5.2 and 6.9 wt%, which points to the medium level of alteration. In the classification diagram Nb/Y vs. Zr/TiO_2 x 0.0001 (WINCHESTER & FLOYD, 1977) analysed rocks are projected in the field of sub-alkaline basalts. High K content coupled with high values of the ratio Th/Yb (1.6-2.0) indicate their high-K calc-alkaline affinity. The lavas show an evolved geochemical character, and are moderately fractioned in terms of Mg# and Cr content (61-64 and 27-41 ppm, respectively). All lavas and tuffs show moderate enrichment of LREE over HREE [$(La/Lu)_{cn}$ = 2.64-4.42] at ~ 38-50 times chondrite relative concentrations. Negative Eu anomaly (Eu/Eu* = 0.81–0.87) indicates early feldspar accumulation or fractionation at low pressure. All rocks show the pronounced negative anomalies of Nb-Ta and Ti relative to La [$(Nb/La)_n$ = 0.32-0.52; $(Ti)_n$ = 0.71-0.76], which is typical for subduction zone magmas. High values of Th/La (0.29-0.32) and Th/Ta (15.1-16.0) ratios may indicate a continental crust contamination (e.g., TAYLOR & MCLENNAN, 1985), but low positive values of initial $\varepsilon_{Nd(241Ma)}$ (2.08) and low values of $^{147}Sm/^{144}Nd$ ratio (0.137967) point to the influence of the subducted juvenile material (subducted slab with little pelagic sediment; SWINDEN et al., 1990). In addition to the enrichment from the fluids derived from the subducted slab it appears that the contamination of magma chamber was facilitated by sediment flux from the ancient, Palaeotethyan, subduction slab, as suggested by the linear trend of Th/Nb values (0.98-1.14) along with a constant Ba/Th ratio (21-27; e.g., LEAT et al., 2000). The origin of the volcanic and pyroclastic rocks of Kuna Gora Mtn. is therefore complex resulting from the above-mentioned processes and events.

In the Hf/3-Th-Nb/16 diagram (WOOD, 1980) the lavas and tuffs are plotted within the orogeny field, unique for calc-alkaline arc-related volcanic rocks, which also suggests a subduction-related nascent environment. Highly-K calc-alkaline character of these rocks and their characterization based on Th/Yb vs. Ta/Yb (GORTON & SCHANDL, 2000) and La/Yb vs. Sc/Ni (BAILEY, 1981) ratios clearly support the origin Kuna Gora Mtn. volcanic and pyroclastic rocks in an ensialic mature volcanic arc setting developed in an active continental margin environment analogue to the Andean-type volcanism. This is in favour of geodynamic evolution that hypothesizes the existence of an active, ensialic and mature volcanic arc developed along the southern active continental margins of Laurussia during late Anisian-early Ladinian northward subduction of Paleotethyan lithosphere. Therefore, such arc-related explosive volcanism from Kuna Gora Mtn. is furthermore featured by inherited geochemical signatures of the Paleotethyan subducted plate.

Keywords: *mineralogy, petrology, Middle Triassic, volcanic rocks, Kuna Gora Mtn., Croatia*

References

BAILEY, J.C. (1981): Geochemical criteria for a refined tectonic discrimination of orogenic andesites. Chemical Geology, 32, 139-154.

GORTON, M.P. & SHANDL, E.S. (2000): From continents to island arcs: A geochemical index of tectonic setting for arc-related and within-plate felsic to intermediate volcanic rocks. The Canadian Mineralogist, 38, 1065-1073.

LEAT, P.T., LIVERMORE, R.A., MILLAR, I.L. & PEARCE, J.A. (2000): Magma supply in back-arc spreading centre segment E2, East Scotia Ridge. Journal of Petrology, 41, 845-866.

OGG, J.G., OGG, G. & GRADSTEIN, F.M. (2016): A concise geological time scale. Elsevier, Amsterdam, 250 p.

PAMIĆ, J. & TOMLJENOVIĆ, B. (1998): Basic geological data on the Croatian part of the Mid-Transdanubian Zone as exemplified by Mt. Medvednica located along the Zagreb-Zemplen Fault Zone. Acta Geol. Hung., 41, 389-400.

SWINDEN, H.S., JENNER, G.A., FRYER, B.J., HERTOGEN, J. & RODDICK, J.C. (1990): Petrogenesis and paleotectonic history of the Wild Bight Group, an Ordovician rifted island arc in central Newfoundland. Contribution to Mineralogy and Petrology, 105, 219-241.

TAYLOR, S.R. & McLENNAN, S.M. (1985): The continental crust: its composition and evolution. Blackwell Scientific Publication, Oxford, 312 p.

WINCHESTER, J.A. & FLOYD, P.A. (1977): Geochemical discrimination of different magma series and their differentiation products using immobile elements. Chemical Geology, 20, 325-343.

WOOD, D.A. (1980): The application of a Th-Hf-Ta diagram to problems of tectonomagmatic classification and establishing the nature of crustal contamination of basaltic lavas of the British Tertiary volcanic province. Earth and Planetary Science Letters, 50, 11-30.

The Significance of the Middle Triassic Cephalopod Bearing Strata in the Vicinity of Kunovac Vrelo, Southern Lika, External Dinarides

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In the area of Kunovac Vrelo, near Gračac in the southern part of Lika (Croatia), a significant cephalopod bearing strata were formerly recognized by many researches (KOCH, 1911; SALOPEK, 1913; SALOPEK, 1914; ŠUŠNJAR et al., 1973; ŠUŠNJAR & BUKOVAC, 1978; GRIMANI et al., 1975). They recorded a rich cephalopod assemblage in the Middle Triassic strata of Ladinian age. SALOPEK (1914) identified *Ptychites, Ceratites, Arcestes, Pinacoceras* and *Gymnites* ammonoid genera, some of which belong to the formerly known *Ceratites trinodosus* ammonoid zone of the Illyrian age, previously dated as of Ladinian age; while other species suggested the transition towards the Ladinian.

Two section were recorded: "Mali Kunovac Vrelo" section (20.8 m thick) and "Kunovac Vrelo" section (3,6 m thick). Two recorded section are considered to be continuous, although a covered interval is present between them. "Mali Kunovac Vrelo" represents the older strata, while the "Kunovac Vrelo" section represents younger strata of the same depositional sequence. In both sections ("Mali Kunovac Vrelo" and "Kunovac Vrelo"), two types of lithofacies have been determined: Limestone facies and Pyroclastic facies. The Limestone facies is present at the beginning of the "Mali Kunovac Vrelo" section and it begins with massive, grey bioclastic limestone beds, containing predominantly shallow-marine biota (algae, echinoids and foraminifera), subordinately pelagic organisms (crinoid fragments), and various amount of lime mud. Limestones with volcaniclastic material conformably overly grey bioclastic limestones. They contain hyaline rock fragments, plagioclase and quartz crystaloclasts, deposited together with carbonate detritus of crinoids and radiolarians, cemented with sparry calcitic cement. The top of the Limestone facies in "Mali Kunovac Vrelo" section is marked by the presence of the limestones with predominantly pelagic organisms (radiolarians, thin-shelled bivalves and crinoids), incorporated within a lime mud. Pyroclastic facies consists of two lithologies: crystaloclastic and vitriclastic tuffs, is present at the very top of "Mali Kunovac Vrelo" section.

The deposition at "Kunovac Vrelo" section began with limestones containing poorly sorted resedimented

limestone bioclasts, together with shallow-marine fossils. Limestones are overlain by pelagic limestones with radiolarians, thin-shelled bivalves, sponge spicules and crinoid fragments. All limestone types have lime mud in intergranular space and scarce volcaniclastic material. The very top of the section is marked again by the presence of Pyroclastic facies, containing crystaloclastic and vitriclastic tuffs.

The majority of cephalopod fauna is collected from the interval of limestones with volcaniclastic material (Limestone Facies) at "Mali Kunovac Vrelo" section. *Ptychites, Arcestes, Gymnites* genera were determined and, for the first time in the External Dinarides, *Reitziites reitzi* species is found, marking the *Reitziites reitzi* ammonoid zone of the Middle Illyrian (VÖRÖS et al., 2003).

The investigated sections imply that in the Upper Illyrian time External Dinarides were severely influenced by volcanism and tectonic activity, causing abrupt changes in sedimentary environments.

Keywords: Middle Triassic, ammonoids, biostratigraphy, External Dinarides, Croatia

References

GRIMANI, I., ŠIKIĆ, K. & ŠIMUNIĆ, AN. (1975): Osnovna geološka karta SFRJ, 1: 100 000, Tumač za list Knin, Savezni geološki zavod Beograd.

KOCH, F. (1911): Prilog geologiji Velebita i hrvatskog krša. Izvještaj montangeološke sekcije za god. 1911. Vijesti geološkog povjerenstva, II., 1911, 17 p.

SALOPEK, M. (1914): O naslagama s okaminama kod Kunovac-vrela u Lici. Prirod. istraž. Jugosl. akad. znan. umjetn., 4, 1-23.

ŠUŠNJAR, M., SOKAČ, B., BAHUN, S., BUKOVAC, J., NIKLER, L. & IVANOVIĆ, A. (1973): Osnovna geološka karta SFRJ 1:100.000. List Udbina L33-128. Institut za geološka istraživanja Zagreb, (1962-1967.), Savezni geološki zavod Beograd

ŠUŠNJAR, M. & BUKOVAC, J. (1978): Osnovna geološka karta SFRJ 1:100.000. List Drvar L33-129. Institut za geološka istraživanja Zagreb (1963-1968.); Savezni geološki zavod Beograd.

VÖRÖS, A., BUDAI, T., KOVÁCS, S., PIROS, O. & SZABÓ, J. (2003): Stratigraphy. In: (A. VÖRÖS, ed.) The Pelsonian Substage on the Balaton Highland (Middle Triassic, Hungary). Geologica Hungarica, Series Palaeontologica, Fasciculus, 55, 13-43.

Accretionary Lapilli from Deep Marine Settings in the Middle Triassic of the Velebit Mts (External Dinarides) – Proof for Resedimentation of the Pyroclastic Material?

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The Middle Triassic age in the External Dinarides was characterised by a significant volcanic activity, as in other parts of the western Tethys. In the Velebit Mts., near Donje Pazarište, a 96 meter thick sedimentary succession with rather unusual occurrence of accretionary lapilli was recorded (formerly described by MARCI et al., 1991). Sedimentary and pyroclastic rocks investigated in Donje Pazarište succession indicate that dominant deposition of carbonate rocks was influenced by severe volcanism lasting from the Late Anisian to the Early Ladinian (SMIRČIĆ et al., 2018). Volcanism was possibly accompanied by tectonic activity forming graben or half graben pelagic basins. Six facies were differentiated in almost continuous vertical succession: 1) Flysch Facies – FF at the beginning of the section, 2) Carbonate Shale Facies – CS, 3) Syneruptively Resedimented Pyroclastic Facies – SRP, 4) Platy Limestones with Pyroclastics Facies – PLP, 5) Limestone Breccia Facies – LB to Slumped Limestone and 6) Chert and Pyroclastic Facies – SLCP at the top. Facies characteristics indicate deposition in the open marine, pelagic environment. Nevertheless, in this pelagic deeper marine realm accretionary lapilli unexpectedly occur in limestone and tuff layers, or form distinct layers composed almost exclusively of these peculiar pyroclastic forms. Presence of accretionary lapilli in the deeper marine settings is not common and not always clear (BOULTER, 1987; CUNNINGHAM & BREAD, 2014).

Accretionary lapilli from the recorded section are spheroidal forms 0.8 to 1.5 cm in diameter. They are large pyroclastic particles with visible internal structure organised as concentric volcanic ash rims around the core. They were formed during explosive subaerial volcanic eruptions, in the volcanic clouds by agglutination of fine ash material with presence of water vapour. Their genesis suggest terrestrial origin by volcanic explosion on land or in shallow marine environments (BOULTER, 1987; SOH et al., 1989; AYRES et al., 1991; McPHIE et al., 1993). Accretionary lapilli found in limestones have rims of coarsely crystalized sparry

calcite and cores made of fine volcanic ash. However, accretionary lapilli found in tuff layers lack the calcite rimes and are completely composed of fine volcanic ash and rare fine crystalized plagioclase and quartz crystals. The occurrence of the accretionary lapilli in the deeper marine settings in the Middle Triassic of the Dinarides indicate that they primarily originated in subaerial conditions but were resedimented to deep marine areas with dominant deposition of pelagic limestones and cherts soon after their formation. This interpretation is confirmed by characteristic of the Syneruptively Resedimented Facies. It is supposed that studied accretionary lapilli originated in subaerial conditions and were primary deposited somewhere in the terrestrial environments where they could have been completely lithified. Once they became robust enough to withstand the transport they were resedimented by turbidity currents to deeper marine/pelagic basin. The depositional characteristics of the Flysch Facies – FF, Syneruptively Resedimented Pyroclastic Facies – SRP, and Slumped Limestone, Chert and Pyroclastic Facies – SLCP (horizontal- and cross-lamination and normal grading) implies possible resedimentation by turbidity currents.

Keywords: *accretionary lapilli, Middle Triassic, External Dinarides, volcanism*

References

AYERS, L.D., VAN WAGONER, N.A. & FERREIRA, W.S. (1991): Voluminous shallow-water emergent phreatomagmatic basaltic volcaniclastic rocks, Proterozoic (1886 Ma), Amisk Lake composite volcano, Flin Flon greenstone belt, Canada. In: FISHER, R.V., SMITH, G.A. (eds.): Sedimentation in Volcanic Settings, Society for Sedimentary Petrology, Tulsa, 20-26.

BOULTER, C.A. (1987): Subaqueous deposits of accretionary lapilli: Significance for palaeoenvironmental interpretations in Archean greenstone belts. Precambrian Research, 34, 231-246.

CUNNINGHAM, J.K. & BEARD, A.D. (2014): An unusual occurrence of mafic accretionary lapilli in deep-marine volcaniclastics on 'Eua, Tonga: Palaeoenvironment and process. Journal of Volcanology and Geothermal Research, 274, 139-151.

McPHIE, J., DOYLE, M. & ALLEN, R. (1993): Volcanic textures – A guide to the interpretation of textures in volcanic rocks. Center for Ore Deposits and Exploration studies, University of Tasmania. 198 p.

MARCI, V., PLETEŠ, G., BOSAK, Ž. & ŠATARA, D. (1991): Prvi nalazi akrecionih lapila u trijaskim naslagama kod Donjeg Pazarišta. Geološki vjesnik, 43, 113-121.

SMIRČIĆ, D., KOLAR-JURKOVŠEK, T., ALJINOVIĆ, D., BARUDŽIJA, U., JURKOVŠEK, B. & HRVATOVIĆ, H. (2018): stratigraphic definition and correlation of the Middle Triassic volcaniclastic facies in the External Dinarides: Croatia and Bosnia and Herzegovina. Journal of Earth Science, 29, 4, 864-878.

SOH, W., TAIRA, A., OGAWA, Y., TANIGUCHI, H., PICKERING, K.T. & STOW, D.A.V. (1989): Submarine depositional processes for volcaniclastic sediments in the Mio-Pliocene Misaki Formation, Miura Group, central Japan. In: TAIRA, A. & MASUDA, F. (eds.): Sedimentary facies and the active plate margines. Terra, Tokyo, 619-630.

Geochemical Atlas of the Republic of North Macedonia

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Beside the research activities on heavy metal pollution in specific areas in the Republic of North Macedonia, information about soil quality on a national level is limited. Therefore, we performed a geochemical investigation of soil across the whole country, and we are pleased to see that this information deficit is being addressed with this project which aims to prepare the first Geochemical Atlas of the Republic of North Macedonia. In this atlas, the basic geochemical properties of soils are described, as revealed by a detailed large-scale survey across the country and analyses of the findings. It will provide a sound, well-structured baseline of soil geochemical properties relevant to sustainable land use and soil management to decision makers in the Republic of North Macedonia in order to reduce the environmental, agronomic and health-related pressures.

The preparation of atlas is the result of a work of the group of prof. Trajče Stafilov and his Ph.D. and M.Sc. students, as well as individual experts from R. of North Macedonia and other countries (e.g. Slovenia, Romania and Russia). The project includes soil sampling and analysis from 1,024 locations with a grid of 5 × 5 km distance between the sampling locations. Each sample represents a mixture of five subsamples to the depth of 0–30 cm. Areas which are known as polluted areas (surroundings of mines, metallurgical factories or larger towns) are investigated taking additional samples on a denser sampling grid (1 x 1 km or 0.5 x 0.5 km). All samples are analysed for contents of about 60 elements. For this purpose, several analytical techniques are applied: inductively coupled plasma – atomic emission spectrometry (ICP-AES), atomic absorption spectrometry

(AAS), inductively coupled plasma – mass spectrometry (ICP-MS) and neutron activation analysis (NAA). All data are statistically processed, and appropriate maps of distribution are prepared for 38 chemical elements.

Based on a comparison of statistical parameters, spatial distribution of particular elements and results of cluster and factor analysis, four main geochemical associations were identified: 1. The association connected with the Neogene and Quaternary volcanism (Ba, Be, Ce, Hf, K, La, Rb, Th, Tl, U, and Zr); 2. Association of siderophile elements (Co, Cu, Fe, Mn, Sc, Ti, and V); 3. Association connected with ophiolites and Mesozoic ultrabasic magmatic rocks of Vardar zone (Cr and Ni) and 4. Chalcophile (sulphide) elements (As, Bi, Cd, Pb, Sb, Sn, and Zn).

Keywords: *geochemistry, atlas, soil, North Macedonia*

A New Upper Jurassic Bauxite Occurrence at Mt. Lugberg, Oberösterreich

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On top of the Upper Kimmeridgian/Lower Tithonian shallow-water limestones of the Wolfgangsee Carbonate Platform, the northernmost part of the Plassen Carbonate Platform Group (GAWLICK et al., 2009) at Mt. Lugberg, we detected a so far unknown bauxite occurrence. It is located at the Eastern end of the Wolfgangsee at Mt. Lugberg at N47°44.623' E13°30.521' (WGS 84). The occurrence is of a lens shape of about 100x50 m size and shows a remarkably flat surface forming a step in the slope. This can either be explained by ancient mining without reported evidence, preferred infilling of an ancient karstic hole or glacial erosion of the soft bauxite. The host rocks are Upper Kimmeridgian–Lower Tithonian open lagoonal near-reefal grainstones to packstones with benthic foraminifera, numerous large crinoid fragments, and dasycladacean algae (SCHLAGINTWEIT et al., 2005).

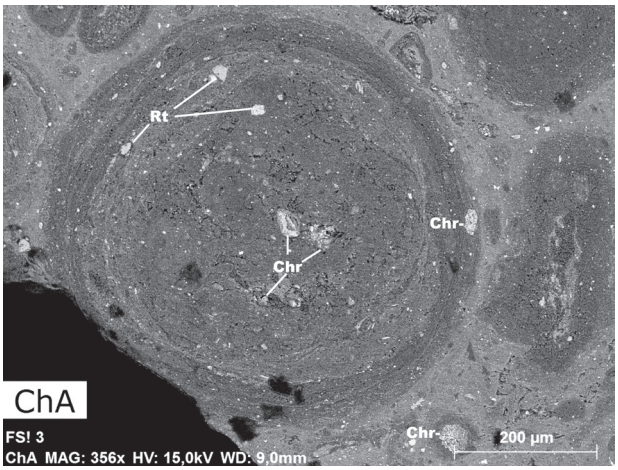

Figure 1. SEM image of a large ooid. Chr = Chromite, Rt = Rutile.

The bauxite was studied using XRD, microscopy and SEM. The XRD yielded boehmite, chromite, and berthierine. The bauxite is hard and has an ooidic texture with a microgranular matrix richer in Si than the ooids which are enriched in Al. The ooids have an average size of 0.3 to 0.5 mm, and there are also few pisoids and their broken fragments, the latter are in some cases incorporated in ooids. Many ooids have cores of iron oxides and hydroxides, rutile, or chromite of presumably ophiolithic origin (Fig. 1). Rare accessory minerals are zircon with up to 3% Hf and monazite. At the margins of the occurrence, iron-rich breccias with carbonate clasts occur, presumably an under-ore breccia over the karstified bedrock (BÁRDOSSY 1982). The bauxite is topped by a layer of silty sand, which is followed by yet undated carbonates of the Plassen Group. The chromites indicate clastic input from the erosion of the obducted Neo-Tethys ophiolites (GAWLICK et al., 2009), whereas the presence of rutile, zircon, and monazite points to evolved felsic rocks in the hinterland. Following the model of PAJOVIC (2009), the occurrence can be classified as a primary karst deposit.

Keywords: *bauxite, Plassen Platform, Upper Jurassic*

References

BÁRDOSSY, G. (1982): Karst Bauxites. Vol. 14. Amsterdam Oxford New York: Elsevier.

GAWLICK, H.J., MISSONI, S., SCHLAGINTWEIT, F., FRISCH, W., KRYSTYN, L., BLAU, J. & LEIN, R. (2009): Jurassic Tectonostratigraphy of the Austroalpine Domain. Journal of Alpine Geology, 50, 1-152.

PAJOVIC, M. (2009): Genesis and Genetic Types of Karst Bauxites. Iranian Journal of Earth Sciences, 1, 44-56.

SCHLAGINTWEIT, F., GAWLICK, H.J. & LEIN, R. (2005): Mikropaläontologie Und Biostratigraphie Der Plassen-Karbonatplattform Der Typlokalität (Ober-Jura Bis Unter-Kreide, Salzkammergut, Österreich). Journal of Alpine Geology, 47, 11-102.

Tracing Tests in the Karstic Catchment of the Gacka River

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Tracing tests are one of the most powerful tools in investigation of karst system hydrogeological properties (GOLDSCHEIDER & DREW, 2007). Tracing typically consists of injection of artificial tracer in a system of karst conduits and afterward monitoring of tracer concentration in discharging water of selected springs. Therefore, it directly reveals underground flow directions, velocities and dispersion within the system. However, considerably different results obtained from repeated tracings of the same sinkhole are common in karst areas (e.g. KUHTA et al., 2010; STROJ et al., 2010). Significant differences are commonly present in apparent groundwater velocities and dispersion, and sometimes even in groundwater directions. Inconsistencies in results of the repetitive tests are usually interpreted as a consequence of different hydrologic conditions within the system during performance of the tests. However, methodology of tracer monitoring in Croatia significantly evolved during 1980s: from detection of tracer using quartz lamp to detection using a laboratory spectrofluorometer. If properly used, spectrofluorometer enables much lower detection limit, i.e. much more reliable tracer detection at low concentrations. In recent years usage of field fluorometers also enabled high temporal resolution of sampling, and consequently determination of very detailed tracer concentration curves. Typically, tracer concentration curves show characteristic and relatively regular shapes, regardless if they are single or multi peaked. Therefore, highly irregular shape of tracer curves obtained by quartz lamp at concentrations close to detection limit gives rise to doubt in positive tracer detection. Within the karstic catchment of the Gacka river springs, several tracing tests were carried out over the time period from 1950s till present. Present knowledge about this regional and complex karst system is largely based on the results of these tests. Recently, a multi-tracer test in medium-low water conditions was performed. Usage of field fluorimeters together with hydrological monitoring enabled acquiring detailed tracer concentration and recovery curves. Despite relatively high tracer recovery, apparent ground flow velocities were much lower in comparison to the previous results. Comparison of results obtained in medium-low flow and in high flow conditions is particularly valuable for comprehensive estimation of karst system properties. Determined flow directions were quite different in comparison to some of the older results (reviewed in PAVIČIĆ, 1997), while they were consistent with more recent ones (KUHTA et al., 2010; KUHTA & FRANGEN, 2013). It can generally be concluded that caution is needed during interpretation of relatively old tracing test results considering determined tracer concentrations to detection limit ratio and concentration curve shape.

Keywords: karst hydrogeology, tracing test, Gacka River springs

References

GOLDSCHEIDER, N. & DREW, D. (2007): Methods in Karst Hydrogeology. Taylor & Francis Group, London, 264 p.

KUHTA, M., FRANGEN, T. & STROJ, A. (2010): Trasiranje ponora na Trnovac polju [Tracink of the sinkhole in the Trnovac polje – in Croatian]. Unpubl. Technical report, Documentation archive of Croatian Geological Survey, Zagreb.

KUHTA, M. & FRANGEN, T. (2013): Trasiranje ponora Šuputove Drage na Homoljačkom polju [Tracing of the Šuputove Drage sinkhole in the Homoljac polje – in Croatian]. Technical report, Documentation archive of Croatian Geological Survey, Zagreb.

KUHTA, M., STROJ, A. & DUKARIĆ, F. (2010): Results of the repeated tracing test of the Markov ponor on the Lipovo polje. In: HORVAT, M. (ed.): 4. Croatian Geological Congress with international participation, 14-15. October, 2010, Šibenik, Croatia. Abstract Book. Croatian Geological Survey, Zagreb, 205-206.

PAVIČIĆ, A., KAPELJ, J., PRELOGOVIĆ, E., KAPELJ, S., BIONDIĆ, D. & HINIĆ, V. (1997): Studija ugroženosti izvorišta rijeke Gacke [Vulnerability study of Gacka river springs – in Croatian]. Unpubl. Technical report, Documentation archive of Croatian Geological Survey, Zagreb.

STROJ, A., KUHTA, M. & DUKARIĆ, F. (2010): Comparison of the Gacka river northern branch sinking area tracing tests results. In: HORVAT, M. (ed.): 4. Croatian Geological Congress with international participation, 14-15. October, 2010, Šibenik, Croatia. Abstract Book. Croatian Geological Survey, Zagreb, 231-232.

Who is Threatened by Cave-Air CO_2? Modrič and Manita Peć Caves (Croatia) Case Study

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Although just a trace gas in atmosphere (412 ppm in April 2019, NOAA), CO_2 plays an important role in overall Earth's system, especially when misbalanced from the natural state. On incomparably smaller scale, CO_2 in cave air is equally interesting in underground environment for its various sources, sinks and effects with and without human interaction. Generally, it governs both limestone dissolution and speleothem deposition (MILANOLO & GABROVŠEK, 2009). Cave-air CO_2 has several sources such as: i) diffusion within epikarst air generated by root respiration and organic matter decay, ii) degassing from the cave water which was enriched by CO_2 on its way through the soil and epikarst, iii) biological productivity (micro-organisms feeding on organic matter, usually guano) and iv) deep-seated (thermal) sources (FAIRCHILD & BAKER, 2012). In addition to natural sources, show caves receive extra anthropogenic CO_2-flux from breathing, which is sometimes recognized as a threat to the vulnerable cave decoration. Namely, elevated pCO_2 in cave air can hamper degassing CO_2 from the dripping groundwater resulting with ceased calcite deposition. Additionally, CO_2 dissolved in water condensed in cave environment may be destructive for already crystalized spelean calcite (FAIMON et al., 2006). On the other hand, impact of the cave air CO_2 on human health is not negligible at certain concentrations, which must be considered both for the visitors and guides in show caves.

The concentration and variation of cave-air pCO_2 is a function both of production and cave ventilation (FAIRCHILD & BAKER, 2012), so for the understanding and reliable reconstruction of natural processes and eventual show-cave management it is necessary to conduct multi-year monitoring of the cave environment. Two relatively small show caves Modrič and Manita Peć have been subjected to the research from 2017 on, in order to estimate interaction and mutual influence between natural cave atmosphere and human presence. Different overlaying bedrock, soil and vegetation cover, morphology and microclimate result with different ventilation pattern and intensity. Manita peć Cave consists of one spacious descending channel, relatively thick but significantly fractured roof, and modest soil and vegetation cover (SURIĆ et al., 2017), so its air circulation keeps CO_2 values bellow 1400 ppm year-round, even during the summer pCO_2 peak. Visitors periodically and temporary increase the pCO_2 for ca. 100 ppm. Modrič cave is shallow horizontal cave developed in two branches. Bushes and recently planted trees, along with thin overburden (SURIĆ et al., 2018), associated with narrow channels produce summer CO_2 concentrations >10 000 ppm. Even during the winter time, the innermost parts retain pCO_2 around 1500 ppm. Given such settings, anthropogenic input of 100-150 ppm of small visitor groups (up to 20 cavers) is insignificant. The main concern in Modrič Cave should be radon activity which profile matches the pCO_2 variations (FAIRCHILD & BAKER, 2012) due to the same ventilation issue, and which is currently under the monitoring.

Keywords: *cave monitoring, CO_2, Modrič Cave, Manita peć Cave, Croatia*

References

FAIMON, J., ŠTELCL, J. & SAS, D. (2006): Anthropogenic CO2-flux into cave atmosphere and its environmental impact: A case study in the Císarská Cave (Moravian Karst, Czech Republic), Science of the Total Environment, 369, 231-245.

FAIRCHILD, I.J. & BAKER, A. (2012): Speleothem Science: From Process to Past Environments. Wiley-Blackwell, Chichester, 432 p.

MILANOLO, S. & GABROVŠEK, F. (2009): Analysis of Carbon Dioxide Variations in the Atmosphere of Srednja Bijambarska Cave, Bosnia and Herzegovina, Boundary-Layer Meteorology, 131/3, 479-493.

NOAA. https://www.esrl.noaa.gov/gmd/ccgg/trends/ (accessed 30 April 2019)

SURIĆ, M., LONČARIĆ, R., LONČAR, N., BUZJAK, N., BAJO, P. & DRYSDALE, R.N. (2017): Isotopic characterization of cave environments at varying altitudes on the eastern Adriatic coast (Croatia) – Implications for future speleothem-based studies. Journal of Hydrology 545, 367-380.

SURIĆ, M., LONČARIĆ, R., BOČIĆ, N., LONČAR, N. & BUZJAK, N. (2018): Monitoring of selected caves as a prerequisite for the speleothem-based reconstruction of the Quaternary environment in Croatia. Quaternary International, 494, 263-274.

Late Quaternary Environmental Changes Recorded in Croatian Speleothems

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Within the last campaign of speleothem-based palaeoenvironmental reconstruction embraced under the REQUENCRIM (HRZZ) project, three caves were selected for the thorough multi-year monitoring and speleothem analyses – Modrič Cave in North Dalmatia, Lokvarka Cave in Gorski kotar and Nova Grgosova Cave in central Croatia (SURIĆ et al., 2018). While Lokvarka Cave speleothems evidenced frequent hydrological changes and associated depositional interruptions, Nova Grgosova and Modrič caves hosted relatively stable conditions, appropriate for the speleothem deposition without strong kinetic isotopic disequilibrium effects. Two speleothems collected from Nova Grgosova Cave appeared to be the best material in terms of U-Th dating and stable isotope ($\delta^{18}O$ and $\delta^{13}C$) analyses, although they covered only the last 10 ka with minimal, but evident isotopic variations characteristic for the Holocene.

On the other hand, three stalagmites from Modrič Cave offer the longest composite speleothem record on the eastern Adriatic coast, with maximum age of 365 ka. Given the relatively large $\delta^{18}O$ and $\delta^{13}C$ ranges (–8.16‰ – –2.97‰ and –13.11‰ – –1.00‰, respectively), it is evident that they recorded significant palaeoenvironmental changes from Oxygen Isotope Stage (OIS) 10 to the Recent, particularly within the OIS 10 – OIS 7, then OIS 6 – OIS 5 and OIS 4 – OIS 2 periods, as well as from OIS 1. Speleothem deposition throughout both glacial and interglacial periods stresses once again the importance of palaeoclimatological studies in Croatia due to its position and varying influences by both Atlantic and Mediterranean air masses.

Keywords: speleothems, stable isotopes, palaeoenvironment, Quaternary, Croatia

References

SURIĆ, M., LONČARIĆ, R., BOČIĆ, N., LONČAR, N. & BUZJAK, N. (2018): Monitoring of selected caves as a prerequisite for the speleothem-based reconstruction of the Quaternary environment in Croatia. Quaternary International, 494, 263-274.

Using Zero Waste Approach for Extraction of Valuable Metals in the ESE Europe Region

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Mining and processing tailings can present a substantial risk to the environment and represent valuable sources of secondary and in particular critical raw materials. Serbia and North Macedonia have an abundance of Cu mines which have been exploited since ancient times. These activities generated about 920 M tonnes of different types of mining, floatation and metallurgical tailings, containing approximately 1.3 M tonnes of Cu, 128 tonnes of Ag and 23 tonnes of Au, which could be a valuable resource for the European raw materials market sector. On the basis of aforementioned two projects were designed, RIS-CuRE and RIS-RECOVER.

The activities of the projects are based on an innovation model merging all relevant stakeholders within the knowledge triangle in the field of industry, research, and education in order to increase regional competitiveness based on a regional scale, taking into account the latest know-how of the RIS-CuRE consortium. This innovative approach is based on the zero waste paradigm, which means that, once valuable raw materials such as CRM and other metals are extracted, the residues can be recycled for the construction sector. Such a holistic eco-innovative approach to the extraction of valuable metals and the beneficial use of residues after the extraction of metals provides a guarantee for the successful development of a regional innovation scheme based on the exploitation of tailings, and is, from the economic, organizational, technological, environmental and social points of view, the most viable option. This will lead to the development of an encouraging environment for the boosting entrepreneurship and intrapreneurship in the region, based on the exploration of secondary deposits. The final output of the project will be a strong sustained regional network, based on validated and fact-based data, including a study of the potential economic, technological, organisational (legislative), environmental and social impacts of applying the innovative methodology of the zero waste extraction of valuable materials in Serbia and the North Macedonia. This will lead to development of encouraging environment for boosting entrepreneurship and entrepreneurship in the region based on exploration of secondary deposits.

Keywords: *raw materials, copper, tailings, RIS-CuRE, ESEE region*

Does Tuff Geochemistry Control its Diagenetic Rate? – Case Study of the Ugljevik Basin Tuffs From the Miocene Pannonian Basin System (NE Bosnia and Herzegovina)

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The Ugljevik or Semberija Basin is located in the Sava Zone of the Dinarides fold-and-thrust belt at the southern margin of the Pannonian Basin System (UNEN et al., 2019, MANDIC et al., 2012). Numerous tuffs from early and middle Miocene are recovered in post-orogenic lacustrine deposits of the Dinarides Lake System (DLS) making a record of an extensive volcanic activity (DE LEEUW et al., 2012, KRSTIĆ et al., 2001). The Ugljevik Basin, in contrast to the most of Dinarides basins, has been affected by the Badenian marine transgression (MANDIC et al., 2019, PAVELIĆ & KOVAČIĆ, 2018). This created relatively stable marine environment, which made diage-

netic patterns of analyzed tuffs more robust compared to those weathered under altering depositional conditions (e.g. ZHAO et al., 2017).

Six middle Miocene tuffaceous horizons (13.86 to 12.6 Ma, MANDIC et al., 2019) intercalated between the marls and limestones were sampled for the purpose of this research. Tuffs show high levels of alteration giving rise to the formation of ubiquitous clay matrix in which only the remnants of volcanic glass are preserved. The loss of ignition values (16.5 to 36.5 wt. %) are in line with the high content of authigenic clay minerals, which are largely consisted of illite and different intermediates of illite-smectite. Calcite is another major mineral, while quartz, muscovite, biotite, plagioclase, K-feldspars and amphiboles represent minor phases. Presence of calcite and aragonite is likely linked to the abundance of fossiliferous content. Chemical composition of tuffs is featured by low amounts of K (K_2O = 0.53-3.18 wt. %) and Na (NaO = 0.05-1.28 wt. %), and strong variations in the content of Ti (TiO_2 = 0.07-0.23 wt. %) and Si (SiO_2 = 20.29-54.90 wt. %). The Nb/Y vs Zr/Ti (PEARCE et al., 1996) discrimination diagram largely defines these tuffs as intermediate rocks, with only one sample classified as rhyolite. Concentrations of HFS elements seem to decrease with time (Hf = 4.63-1.22 ppm, Ta = 2.6-0.28 ppm), while the Mg# and Cr concentrations exhibit the opposite trend (Mg# = 33.63-89.5; Cr = 9.3-118 ppm). Generally, the original magmatism must have been evolved (~6-40 times chondrite concentrations) with a modest enrichment of LREE over HREE [$(La/Lu)_{cn}$ = 6.00-11.34].

A clear trend has been documented between the crystallinity of the main alteration product of tuffs – illite-smectite – and the age of tuffs, which in turns reflects a decrease in magmatic evolution of tuffaceous geochemistry (Fig. 1). Thus, well-crystallized but disordered illite-smectite (FWHM = ~0.8°) dominates in younger and less evolved tuffs, while in the older ones, more evolved in nature, a poorly crystallized illite-smectite (FWHM = ~1.42°) renders a major alteration product. We hypothesize that the reactiveness of less evolved magmatic material, prone to deuteric alterations, may explain the correlation patterns presented herein. Future research which will include larger dataset and additional techniques will lend further insights into the problematic of diagenetic evolution of Miocene tuffs from DLS.

Keywords: *tuffs, diagenesis, Dinarides, southern Pannonian Basin, clays, mineralogy*

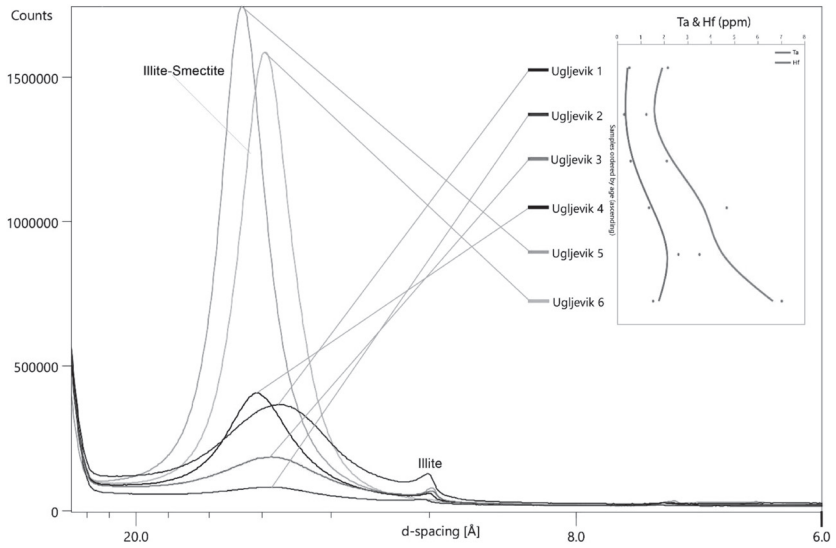

Figure 1. The correlation between the illite-smectite crystallinity and concentrations of HFS elements (samples ordered by ascending age).

References

DE LEEUW, A., MANDIC, O., KRIJGSMAN, W., KUIPER, K. & HRVATOVIĆ, H. (2012): Paleomagnetic and geochronologic constraints on the geodynamic evolution of the Central Dinarides. Tectonophysics, 530-531, 286-298.

KRSTIĆ, N., DUMURDŽANOV, N., OLUJIĆ, J., VUJNOVIĆ, L. & JANKOVIĆ-GOLUBOVIĆ, J. (2001): Interbedded tuff and bentonite in the Neogene lacustrine sediments of the central part of the Balkan Peninsula. A review. Acta Vulc., 13, 91-99.

MANDIC, O., DE LEEUW, A., BULIĆ, J., KUIPER, K., KRIJGSMAN, W. & JURIŠIĆ-POLŠAK, Z. (2012): Paleogeographic evolution of the Southern Pannonian Basin: 40Ar/39Ar age constraints on the Miocene continental series of northern Croatia. Int. J. Earth Sci. (Geol. Rundsch.), 101, 1033-1046.

MANDIC, O., SANT, K., KALLANXHI, M.-E., ĆORIĆ, 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). Glob. Planet. Chan., 172, 374-395.

PAVELIĆ, D. & KOVAČIĆ, M. (2018). Sedimentology and stratigraphy of the Neogene rift-type North Croatian Basin (Pannonian Basin System, Croatia): A review. Mar. Petrol. Geol., 91, 455-469.

References

PEARCE, J.A. (1996): A users guide to basalt discrimination diagrams. In: WYMAN, D. A. (ed.): Trace Element Geochemistry of Volcanic Rocks: Applications for Massive Sulphide Exploration. Short Course Notes 12. St. John's, Canada, Geol. Assoc. Can., 79-113.

VAN UNEN, M., MATENCO, L., NADER, F.H., DARNAULT, R., MANDIC, O. & DEMIR, V. (2019): Kinematics of foreland-vergent crustal accretion: inferences from the Dinarides evolution. Tectonics, 38, 49-76.

ZHAO, L., ZHU, Q., JIA, S., ZOU, J., NECHAEV, V. & DAI, S. (2017). Origin of Minerals and Critical Metals in an Argillized Tuff from the Huayingshan Coalfield, Southwestern China. Minerals, 7, 92.

Subaerial Exposure Surface Within the Palaeocene Carbonates of the Likva Cove, the Island of Brač

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Discontinuity surfaces are common in successions of carbonate platforms, including the Adriatic Carbonate Platform (AdCP). The end of the AdCP deposition is marked by a regional unconformity between the Cretaceous and Palaeogene, but in some parts of the platform sedimentation was more or less continuous across the K/Pg boundary, like in the Likva Cove, NW part of the Island of Brač. In the Likva Cove the youngest deposits of the Sumartin formation belong to the early Palaeocene, corresponding to the lower part of the Liburnian deposits of Slovenia and marking the Maastrichtian-Palaeocene transition.

The studied section of the Palaeocene part of the Sumartin formation is 15.70 m thick and is characterized by lacustrine and shallow marine carbonates with freshwater influence. These carbonates are poor in fossil remains, such as benthic foraminifera, which would enable exact age determination, but the younger Palaeocene-Eocene? age is assumed since the studied section overlies the oldest Palaeocene (Danian) strata previously dated. In its lower part, the studied section comprises subaerial exposure surface characterized by the processes of soil formation in a terrain rich in vegetation under conditions of semiarid climate. The surface is characterized by irregular relief, biogenic calcretes with rhizoliths, *Microcodium* aggregates, alveolar septal fabric, micrite nodules, black pebbles and laminated calcretes and pisoids, indicating long-term subaerial exposure. It may be assumed that a complete meteoric diagenetic zone has been developed under the emerging surface. The subaerial exposure was followed by the transgression resulting in incorporation of fragments of terrestrial carbonates into the clayey calcareous matrix, forming transgressive breccia (including bauxite occurrences) most likely preserved in the palaeodepressions. Above the transgressive breccia brackish to freshwater limestones with ostracods, gastropods, cyanobacteria and charophytaceans have been deposited, indicating a very shallow and restrictive lacustrine environments, as well as certain marine influence. Within the brackish and freshwater limestones several subaerial exposure surfaces have been identified, probably as a consequence of a synsedimentary tectonic activity.

The studied subaerial exposure and erosion surface probably formed under the influence of the Late Cretaceous synsedimentary tectonics caused by initial stages of the collision of the Adriatic microplate and Eurasian plate, and is recognized as a regional event over the entire Adriatic Carbonate Platform, marking the end of the typical carbonate shallow-marine sedimentation.

Keywords: *subaerial exposure surface, Palaeocene carbonates, Adriatic Carbonate Platform, Island of Brač*

Additional Investigation Works on the Geological Profile Bridge Pelješac

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The construction of the Pelješac bridge represents a capital project in Croatia. The bridge had various conceptual solutions, but with the latest requests by Bosnia and Herzegovina, the concept was adopted: Extradosed Cayble-stayed bridge (Pointing Consulting Engineers and Pipenbaher Consulting Engineers). The length of the bridge from the abutment axis to the abutment axis is 2,404 m, while the total length of the bridge is 2,440 m. The fairway profile below the future bridge is 200 x 55 m. The bridge is construct on the 2 abutments with 12 peers. The central system is a bridge with 6 low pylons at the S5–S10 peers so that the bridge symmetry in the space is achieved.

By changing the bridge design, the bridge peers positions changed. New investigation works had the task of exploring new peers foundation and determining depths to the base rock. The client sought the most accurate geological prognosis profile with the most accurate depth to the base rock, to make the piles in one peace with a very accurate length so that they are doing less cutting as possible. Minimum boreholes lengths are assumed according to the prediction geological profile, but the main requirement for the length of the borehole is prescribed: „The final length of the borehole must be at least 12 m in a solid rock (limed limestone) due to the possibility of the existence of a cavity in karst under the peers foundation."

The completed additional investigation works included 18 boreholes on the peers foundation location and 2 boreholes for test pilots distant from the bridge axis for about 40 m (ŠIMOVIĆ & MIKLIN, 2018). Four types of foundations are foreseen. The abutments U1 and U14 have shallowly foundation on a solid rock. Peers S2 i S13 are based on „wells foundation". Peers S3, S4, S10, S11, S12 are based on steel piles completely filled with concrete with an extended concrete feet. Peers S5, S6, S7, S8, S9 are based on steel piles that are filled with concrete to a depth of 40 m. On the sea level piles are anchored in concrete pile cap. In the peers positions of the S3, S4, S11, S12, there are 9 piles in the 17.0 x 17.0 m concrete piles cap, S5, S6, S9, S10 having 18 piles and 23.0 x 29.0 m concrete piles cap, S7 and S8 have 20 pilots in the concrete piles cap 23.0 x 29.0 m.

Steel piles are 2000 mm in diameter with a 40 mm steel wall thickness S335 and S460. The pile lower part of the 2 m length is reinforced (steel grade S460) and the steel wall thickness is 60 mm. Piles construction began in mid-January 2019 Final piles were completed by the end of April and with that the first phase of the works ended. The result of the investigation work is also visible in the construction of piles, in the locations without overlay the piles are almost perfectly construct, while in case we have a thick overlay depth to the base rock they vary from the sea level.

In the main design, the foundation calculations were made in software Plaxis 8, and after additional investigations, for S6 peer foundation calculation was done in Ensoft Inc – Engineering + Software – Apile 2018. The piles were tracked by Pile driving (PDA) analyzer during construction to track pressure and tensile stresses, stresses on pile feet, pilot integrity, hammer energy transfer and piles bearing capacity based on the CASE calculation and signal matching process (CAPWAP).

The results were satisfactory and almost identical, which confirms that the assumptions taken in the calculations are accurate.

Interesting was the bearing capacity behavior of piles in time. The first results were below the calculated bearing capacity because the SETUP effect has not yet been activated. But after each re-test the bearing capacity grew because the friction on the shaft was activated after the consolidation of the surrounding clay. The testing program was looking for testing 1, 3, 7, 14, 28 days but after 10 days it was no longer possible to move the piles with the energy of the hammer. In the final analysis, the superposition method had to be used.

Keywords: *bridge, piles, piers*

References

ŠIMOVIĆ, J. & MIKLIN, Ž. (2018): Most kopno-Pelješac. GT 0030 Elaborat o provedenim istražnim radovima stupište S6. Tempusprojekt 294/18. Zagreb., Pelješac bridge – GT-0030-Geotechnical investigation works study for peer S6. Tempusprojekt 294/18. Zagreb.

Sedimentology and Architecture of Pleistocene Škrile Alluvial Fan, Stara Baška, Krk Island, Croatia

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Alluvial fans represent a typical feature of mountain fronts, with ideal conditions for their formation. This position is related to the clast availability, suitable relief characteristics (slope break), and availability of transport medium. Here we report on Pleistocene alluvial fan (Škrile alluvial fan, Stara Baška) on Krk Island in the NE Adriatic Sea, i.e. from the area that today does not meet the climate criteria (neither temperature nor precipitation) for the fan formation. Today, the fan is sedimentologically inactive, it is covered by thin soil profile overgrown by the forest and intensively eroded. The cliff erosion on the contact of the fan and sea almost perfectly exposed a transverse cross-section of the fan while the longitudinal cross-section of the fan is exposed in an erosional torrential ravine (Fig. 1).

The catchment area of the fan is mainly composed of Upper Cretaceous rudist limestone, disconformably overlain by upper Paleocene to lower Eocene foraminiferal limestone. Disconformity is marked by karst paleotopography and sporadic bauxite deposits. Structurally, the area is defined by two large anticlines and intermediate syncline, cut by two NW-SE (Dinaric) faults and numerous connecting faults.

The Škrile fan is composed of 4 sedimentary facies deposited in up to few decimetres-thick intercalated beds that form complex meter-scale facies mosaic. The facies are represented by poorly- to well-sorted breccias (Facies A), gravelly sandstones (Facies B), poorly to well-sorted breccia with sandy-silty matrix (Facies C) and sandy and gravelly mud (Facies D). The sediments are deposited in beds (few centimetres to over 1 meter thick). The bed contacts are mainly sharp, concordant and erosive, with bedding defined by vertical and lateral changes in the mean grain size. Beds are structureless or exhibit normal and inverse grading, and locally cross-bedding and clast imbrication. In transverse section, the fan succession exhibits complicated meter-scale facies association with different facies eroding and overlapping each other. The majority of beds are intercalated lensoid sedimentary bodies with lateral continuity of up to few meters forming complex internal geometry of the fan.

Facies A and B represent sieve lobe deposits accumulated from unchannelized (sheet) flows. These facies also commonly exhibit a fining-upward trend locally with outsize clasts in the upper part of beds. This finning upwards is related to waning flow velocities following sheet floods. Facies C represents typical features of ruditic channel flows of torrential flows forming braided fluvial succession. The succession is dominated by stacked point bars and a number of channel fills. Differences in grains sizes and size of channels and bars indicate variations in slope angle and stream power. Combination of facies A, B and C, therefore, represents laterally and vertically associated and interfingering sieve lobes and braided fluvial deposits located in

Figure 1. Photo of Škrile fan, outcrop with transverse cross-section.

the middle- to distal fan environment. Facies D represents debris flow deposit that occurs exclusively near the contact of the fan and the flysch bedrock.

Today the Škrile alluvial fan is inactive and represents an ancient alluvial fan formed in a different climatic and/or tectonic regime. From the tectonic point of view, the research area is suitable for fan formation with clearly defined Upper Pliocene tectonic reactivation that is still active today. Therefore, the main factors limiting active fan deposition are related to the rate of clast formation (physical weathering due to the frost cracking) and the frequency and magnitude of transport events. We assume that that growth or retreat of glaciers in the source area may exert a key control on the fan system. Namely, the peak sedimentation and evolution of such an extensive fan system usually occur during a glacial retreat with high clast availability and production, and abundance of snowmelt rapids and/or heavy rainfall which facilitate sediment transfer to the fan site. Thus, we tentatively determined the age of the fan as post-middle Pleistocene.

Keywords: sieve deposits, channel flow deposits, glaciation

Delineation of the Deep Geothermal Aquifers in the DARLINGe Project Area

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The Croatian Geological Survey as one of the project partners, conducted DARLINGe project in the period from January 2017 until September 2019. In the DARLINGe project 15 partners representing national geological surveys, university, ministry, industry, regional energy and municipality and 7 associated strategic partners from 6 countries of the Danube Region (HU, SI, HR, SRB, BiH, RO) worked together to contribute to energy security and energy efficiency in the Danube Region. The principal project objectives were to enhance the efficient use of deep and still untapped geothermal resources in the heating sector and promote efficient use of cascade systems. The project area covers about 95 000 km^2 where there are two types of geothermal reservoirs, located in a multi-layered porous rocks within the sedimentary basins, and in the fissured, fractured and karstified rocks in their basement. Within the project area, three cross-border pilot areas were selected to test the developed methodologies. For the achievement of the required results in terms of increasing the use of geothermal energy in the heating sector, the main geothermal reservoirs had to be delineated within the given area. A unique methodology was developed based on the common geological, hydrogeological and geothermal features typical for the Pannonian basin (ROTÁR-SZALKAI et al., 2018).

According the lithology and porosity, two important geothermal reservoir types were determined: i) basin fill reservoir (BF) and ii) basement reservoir (BM). BF reservoirs represent Upper Miocene-Pliocene "Pannonian" basin fill sequence (sands with primary porosity), whereas BM reservoirs consist mostly carbonate, crystalline (e.g., granite, granodiorite, gabbro, gneiss, mica-schist,) and subordinately volcanic (e.g., andesite, basalt) formations characterized by dominant secondary porosity because of weathering, karstification and tectonism (ROTÁR-SZALKAI et al., 2018). In this study, identification and subsurface mapping of the geothermal reservoirs was carried out by applying

SURFER and ArcGIS software: BM – top basement surface of the formations (the Pre-Cenozoic basement), which represents the BM-top without the Senonian sediments; BF-basin fill bottom surface – the shelf-edge of the Pannonian Lake, representing a shale-sand lithological boundary; BF – basin fill top, the top surface of the shelf sediments.

Consequently, within the scope of the DARLINGe project the isotherm maps based on the conductive model were also created.

Acknowledgments

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Keywords: *deep geothermal aquifers, geological units, geothermal maps, Pannonian Basin*

References

ROTÁR-SZALKAI, Á., MAROS, G., BERECZKI, L., MARKOS, G., BABINSZKI, E., SEBESS, L.Z., GULYÁS, Á., KUN, É., SZŐCS, T., KERÉKGYÁRTÓ, T., NÁDOR, A., ÁDÁM, L., RMAN, N., RAJVER, D., LAPANJE, A., ŠRAM, D., MARKOVIĆ, T., VRANJEŠ, A., FĂRNOAGA, R., BALTRES, A., COCIUBA, I., OLAH, Ş., SAMARDŽIĆ, N., HORVATOVIĆ, H., SKOPLJAK, F. & JOLOVIĆ, B. (2018): D.5.1.1. Identification, ranking and characterization of potential geothermal reservoirs. Project DARLINGe. Internet: http://www.interreg-danube.eu/approved-projects/darlinge/outputs.

The Koločep Channel – A Sedimetary Record of Late Quaternary Paleoseismic History in a Submerged Karst isolation Basin

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During the Last Glacial Maximum (LGM), the Koločep Channel was an isolated karst basin separated by a sill from the rest of the Adriatic Sea. The channel is situated between the eastern Adriatic coast and Elaphite Islands in southern Dalmatia. The recent coast has been shaped by the last sea-level rise during the Late Pleistocene and Holocene, when the faulted, folded and karstified relief was partially submerged (PIKELJ & JURAČIĆ, 2013). The sedimentation in the Koločep Channel during the Late Pleistocene and Holocene was under influence of climate and sea-level changes. As a result, different depositional environments developed.

The wider region is tectonically active and characterized by moderate to strong earthquakes generated by convergence of Adriatic and European plates. The number and intensity of earthquakes along the eastern Adriatic coast increases from NW to SE, with the greatest number of earthquakes in Ston and Dubrovnik area (KUK et al., 2000). Compressional tectonic movements accommodated by reverse faults have the major tectonic impact on the formation of the relief.

The evidence of the Late Pleistocene-Holocene tectonic activity is visible on the high-resolution seismic profiles acquired in Koločep Channel by sub-bottom Chirp profiler, with penetration of about 50-60 m and a vertical resolution of about 0.5 m. Seismic profiles enabled reconstruction of geomorphology and depositional environments in the study area. On the high-resolution profiles 9 acoustic units have been recognized and interpreted. Based on the results, alteration of marine and lacustrine deposits was determined. Deposits accumulated during the Late Pleistocene and Holocene in most of the basin area are horizontal, implying tectonic stability. Therefore, it appears that most of the faults in the central part of the basin were not active during the Holocene. However, in the southern rim of the basin, between the Šipan Island and the mainland, a fault zone was observed in high-resolution seismic profiles, which deformed the Holocene marine deposits and the seafloor, indicating that it is an active tectonic structure. The entire sedimentary sequence indicates subvertical uplift of a Mesozoic bedrock block of approximately 10 m. Based on the location of the 1996 Ston earthquake epicentre it is possible that the seismic activity in the Stone area is related to this structure.

Keywords: *Koločep Channel, karst environment, morphology, sub-bottom profiles*

References

KUK, V., PRELOGOVIĆ, E. & DRAGIČEVIĆ, I. (2000): Seismotectonically Active Zones in the Dinarides. Geologia Croatica, 53, 2, 295-303.

PIKELJ, K. & JURAČIĆ, M. (2013): Eastern Adriatic coast (EAC): Geomorphology and costal vulnerability of a karstic coast. Journal of Costal Research, 29, 4, 944-957.

Regional Center Adria EIT RawMaterials Hub

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KIC EIT RawMaterials is one of many Knowledge and Innovation Communities (KICs) operating under the umbrella of European Institute of Innovation and Technology (EIT). EIT RawMaterials vision is to develop raw materials into a major strength for Europe. Its mission is to enable sustainable competitiveness of the European minerals, metals and materials sector along the value chain by driving innovation, education, and entrepreneurship. EIT RawMaterials is a pan-European partner network covering entire raw material value chain with more than 120 Core and Associated partners from all three sides of Knowledge Triangle – research, education and industry, thus representing the world's largest community in the raw materials sector. Slovenia and Croatia belong to the Eastern Co-location Center and are represented by two Slovenian partners (Geological Survey of Slovenia and Slovenian National Building and Civil Engineering Institute) and one Croatian partner (Faculty of Mining, Geology and Petroleum Engineering University of Zagreb).

To achieve radical innovation along the Raw Materials Value Chain the following knowledge and innovation themes are defined: Exploration, Mines for Modern Society, Develop and improve processing, Substitution, Recycling and Circular Economy. These themes are addressed with three groups of activities: 1.) Matchmaking and networking, 2.) Acceleration and 3.) Education Activities. Specific activities within the EIT Regional Innovation scheme (RIS) focus on countries with limited or no participation in the EIT Community's activities, where innovation capacity is moderate or modest (by European Commission Scoreboard) and which otherwise would not be able to benefit from the experience gained by the KICs.

Most activities implemented by Slovenian and Croatian partners are funded as Regional Innovation Scheme projects, focusing on involvement of Eastern and South-Eastern European (ESEE) countries in the KICs activities. With the same mission Regional Center (RC) Adria – EIT RawMaterials hub was established in the beginning of 2018, so 2019 is our second implementation year. RC Adria's has three founding members (all three mentioned institutions) covering Slovenia and Croatia with an outreach to SEE/Western Balkan countries (Albania, Bosnia and Herzegovina, Montenegro, North Macedonia and Serbia).

RC Adria's basic activities are:

– Interface between EIT RawMaterials and local RIS SEE knowledge triangle
– Offer information about EIT RawMaterials funding, networking events, new potential business partners, project ideas and business support for stakeholders from SEE region
– Provide expertise to national, regional and local authorities
– Mobilise, connect and internationalise national/regional networks
– Identify funding and project opportunities
– Contribute to project 's development and implementation

In 2019 RC Adria's most important activities are:

Two matchmaking and networking events – one in Croatia and one in Slovenia:

Croatia Waste Expo and **Industry Symbiosis Workshop** will be organised on 22 October 2019 in Zagreb with goal in networking and formation of cross resource recovery matches in Adria region under a topic "Utilisation of secondary raw materials – boosting transition to circular economy". Target groups for this event are professionals, associations and consultants working with waste producers and potential end-users in the field of metallurgical sector, mining sector, paper industry, municipal waste sector and other industries as well as waste holders, brokers, dealers, transporters, waste treatment operators.

ADRIA Innovation Day 2019 with a title Innovation in Primary and Secondary Raw Materials Sector in the South-East Europe is going to be held on 23 October 2019, in Hoteli Bernardin, resort and conference centre in

Portorož, Slovenia. ADRIA Innovation Day is a one-day event aiming to present available opportunities for the business sector under the EIT Raw Materials and the Regional Center ADRIA to enhance raw materials network in the South-East Europe. Invited speakers and participants of the ADRIA Innovation Day are professionals from business organizations in primary and secondary raw materials sectors - large companies, SMEs, Start-ups or idea holders, decision and policy makers as well as business support organizations from Slovenia, Croatia and other countries from the region (Albania, Bosnia and Herzegovina, Montenegro, North Macedonia, Serbia). Event is co-organized by Geological Survey of Slovenia and Slovenian National Building and Civil Engineering Institute.

Internship programme for ESEE raw materials students is an on-going pilot project aiming to develop a structured internship programme for ESEE students. Students of the final year of graduated study in Mining, Geosciences, Metallurgy; Waste management form Croatia, Slovenia and ADRIA region can apply to participate at internship in ADRIA companies and institutions at https://www.rgn.unizg.hr/en/online-application-for-adria-internship-programme. Companies and institutions working in Mining, Geosciences, Metallurgy; Waste management form Croatia, Slovenia and ADRIA region can apply to accept interim students http://www.rgn.unizg.hr/en/online-application-adria-internship-programme-for-companies. Internship programme lasts between 1 and 3 months and must be conducted in year 2019. Structured supervision and conduction of the internship will be ensured via webinar support for both supervisors and interim students.

RawMaterials business idea development will be conducted in Zagreb in the last quarter of the 2019 with main aim to develop 20 RawMaterials innovative with practical exercise and idea pitches. Several participants of the programme (idea-holders) will be selected for participation in the EIT Jump-starter follow-up programme, starting in February 2020.

Keywords: EIT RawMaterials, Regional Center Adria, activities, networking, innovation

Urban Geochemistry and Environmental Risk Assessment of Selected Elements in the Sisak Region, Croatia

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A geochemical investigation of the urban area of the city of Sisak and its surroundings was carried out to determine the concentration and spatial distribution of the potentially toxic elements (PTEs) As, Ba, Cd, Cr, Co, Cu, Hg, Mo, Ni, Pb, Tl, V and Zn in the soil and to assess the risk for the environment and human health. The elements were selected according to proposal of the PTEs in soils in the project Development of the program for permanent monitoring of the Croatian soils with a pilot project (MESIĆ et al., 2008).

The city of Sisak is an old Roman settlement, with a developed transport network and heavy industry. The city is located on siliciclastic Quaternary alluvium deposits of the rivers Kupa and Odra, carbonate deposits of the river Sava and loess (PIKIJA, M., 1987a,b). Topsoil samples were collected at 144 sampling locations according to the URGE procedure manual of the EuroGeoSurveys Geochemistry Expert Group (DEMETRIADES & BIRKE, 2015a), with the exception that a composite sample was taken at each sampling location. Multi-element chemical analysis was performed at Acme Labs Vancouver, Canada, by ICP-MS (ŠORŠA et al., 2017). Quality control of the sampling procedures and laboratory analytical results was performed in accordance with the methods described in REIMANN et al. (2009) and DEMETRIADES & BIRKE (2015b).

The potential risk for human health of the individual PTE and potentially cumulative risk of all selected PTEs were assessed based on the comparison of metal concentrations in the soil and its prescribed limit values in soil versus land use (MESIĆ et al., 2008). There is no risk for human health for As, Cd, Co, Cr, Hg, Mo and Tl in the whole investigated area. A low risk for Ba, Cu, Ni, Pb, V and Zn was observed in some agricultural areas and for Pb along the more frequented roads. The elevated content of PTEs was recorded in old town Sisak. The highest values of PTEs in soil in the investigated area was detected around industrial facilities in the south and represent a threat for the adjacent settlements Kanak, Caprag, Capraške Poljane and Crnac (ŠORŠA & HALAMIĆ, 2014). Considerable

contamination with Ba, Pb and Zn was observed in the Kanak area which is located between a steel works, refinery and thermal power plant. The settlement Kanak is polluted with Ba, Pb and Zn and has the highest cumulative risk (18.61) for health and environment in the entire investigated area (Fig. 1).

Keywords: potentially toxic elements, urban soil, risk assessment, pollution, land use

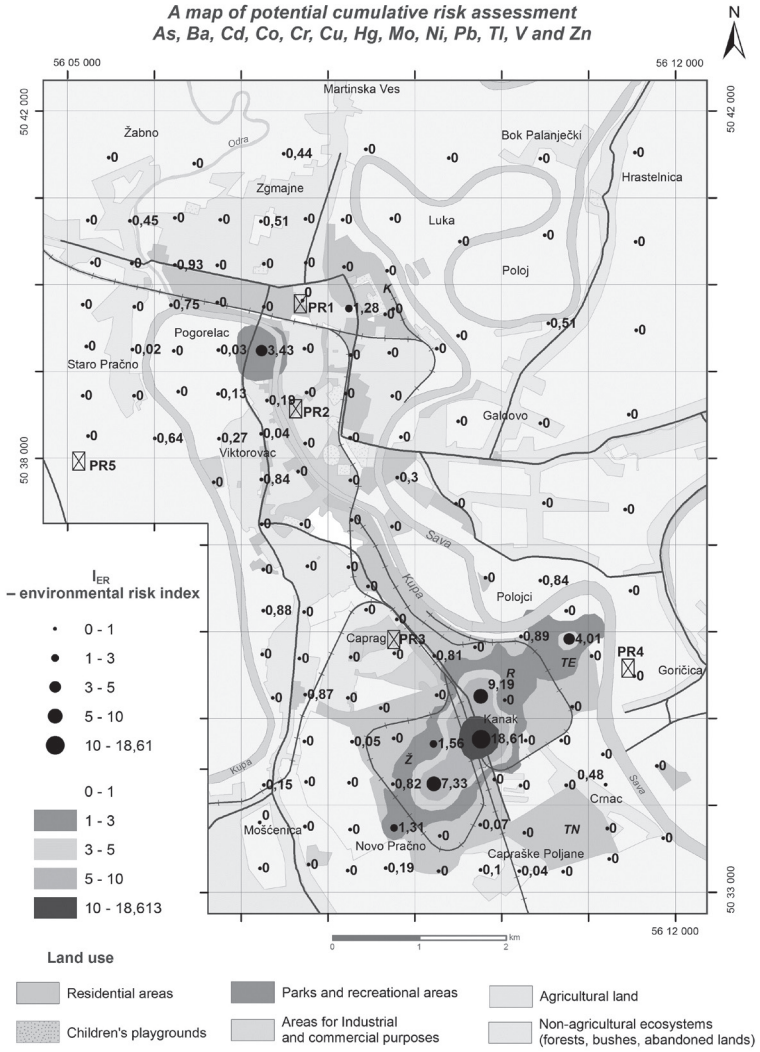

Figure 1. A map of potential cumulative risk assessment.

References

DEMETRIADES, A. & BIRKE, M. (2015a): Urban Topsoil Geochemical Mapping Manual (URGE II). EuroGeoSurveys, Brussels, 52 p.

DEMETRIADES, A. & BIRKE, M. (2015b): Urban Geochemical Mapping Manual: Sampling, Sample Preparation, Laboratory Analysis, Quality Control Check, Statistical Processing and Map plotting. EuroGeoSurveys, Brussels, 162 p.

MESIĆ, H., ČIDIĆ, A., DOMINIKOVIĆ ALAVANJA, S., KISIĆ, I., BAŠIĆ, F., ZGORELEC, Ž., HUSNJAK, S., ROMIĆ, D., KOMESAROVIĆ, B., KLAIĆ, D., PERNAR, N., BAKŠIĆ, D., VRBEK, B., PILAŠ, I., POTOČIĆ, N., SELETKOVIĆ, I., DURN, G., MILEUSNIĆ, M., NAKIĆ, Z. & MIKO, S. (2008): Development of the program for permanent monitoring of the Croatian soils with a pilot project. In: DRAGIČEVIĆ, S.K. (ed.): The Program for Permanent Monitoring of the Croatian Soils. Croatian Environment Agency, Zagreb, 131 p.

PIKIJA, M. (1987a): Basic Geological Map of SFRJ. 1: 100,000, Sheet Sisak L33–93. Geological Institute Zagreb (1975–1986). Federal Geological Institute, Beograd.

PIKIJA, M. (1987b): Basic Geological Map of SFRJ. Explanation for the Map Sheet of Sisak L33–93. Geological Institute Zagreb, Federal Geological Institute, Beograd, 55 p.

REIMANN, R., DEMETRIADES, A., EGGEN, O.A., FILZMOSER, P. & The EuroGeoSurveys Geochemistry Expert Group (2009): The EuroGeoSurveys geochemical mapping of agricultural and grazing land soils project (GEMAS) – evaluation of quality control results of aqua regia extraction analysis. In: Geological Survey of Norway, NGU Report 2009. 049., 94 p.

ŠORŠA, A., DURN, G., HALAMIĆ, J., HUSNJAK, S., GARAŠIĆ, V. & MILEUSNIĆ, M. (2017): Urban geochemistry: Sisak in Croatia, a long-lasting historical, urban and industrial city. GEEA, 17, 159-163.

ŠORŠA, A. & HALAMIĆ, J. (2014): Geochemical Atlas of Sisak. Public Library Vlado Gotovac Sisak, City Museum Sisak and Croatian Geological Survey, Sisak-Zagreb, 200 p.

Sedimentary Basin Fill of Lake Pannon in the Eastern Part of Drava

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Lake Pannon was filled by rapid sedimentation during the Late Miocene to Pliocene. The initially vast and deep lake was finally infilled by large sediment input, significantly exceeding the creation of accommodation space. Despite various sedimentological, paleontological and seismic stratigraphy-related research, there is still little knowledge about different factors that were shaping the geometry of this basin infill. These uncertainties can be resolved by an integrated study of the clinoforms system. More precisely, it can help in better understanding of the interplay between shelf-edge trajectory, direction of sedimentary transport, spatial distribution of paleoenvironments, and basin morphology (paleobatimetry) combined with local tectonic events (TOMLJENOVIĆ & CSONTOS, 2001).

The study is situated in the Eastern part of the Drava basin, in the area between Slatina and Valpovo. Numerous seismic horizons, mapped on 3D seismic data, were used for the construction of structural and thickness maps in the time domain. Seismic attributes, like RMS amplitude and spectral decomposition, were applied on the data as well. For the purpose of well to seismic ties, VSP and checkshots data were used. Geological age estimation of seismically defined and mapped horizons is based on existing stratigraphic logs from deep wells in the area. Some of these data are old.

Based on seismic facies, two generations of clinoforms can be distinguished, a thicker older, and a thinner younger set. The first set is composed of 255 ms high sigmoidal clinoforms in the western area, indicating a water depth of ca. 610 m. During their deposition, the shelf-margin trajectory was flat, until maximum regression was reached. Then, the second generation of clinoforms appears, showing oblique shape in the west, with downlap features to the east. Their height is increasing in the same direction, where clinoforms start to develop sigmoidal architecture, like in the older thicker set, with an interpreted depth of water column of ca. 190 m to 270 m.

Seismic sections, structural, thickness and seismic attributes maps, show that delta progradation happened before or during the initiation of basin inversion in this area (BALÁZS et al., 2016; SAFTIĆ et al., 2003). Prograding slope reached this area between 6.8 Ma and 5.3. Ma ago, and then, during the inversion, the whole studied sequence was tilted to the southwest. Observations confirmed that delta progradation occurred from the present day northwest and continued to the southeast. Distributary channels and basin floor lobes orientation are indicating that sedimentary input patterns may be gently influenced by inherited structures. Furthermore, different stratal stacking patterns are revealing lacustrine base level fluctuations. The flat trajectory of first clinoform progradation suggests steady base level, which continued to maximum regression, when the slope related canyons also developed (SZTANÓ et al., 2013). This event was followed by base level rise of more than 200 m. As a result, the second generation of smaller clinoforms prograded on the new shelf and over the old slope. Similar events of base-level rise are common in Lake Pannon, nearby in the northern part of the Drava basin (UHRIN & SZTANÓ, 2012), yet far less than 100 m (SZTANÓ et al., 2013; BALÁZS et al., 2018), while much larger in the Eastern part of the Great Plain. Moreover, infilling patterns were probably influenced by local structures and basin topography, possibly connected to the large-scale tectonic events in this marginal part of Pannonian basin system.

Despite many similar studies were done inside the industry (IVKOVIĆ, 2000), this is the first published seismic study with focus on timing and factors controlling the morphological shelf-slope progradation, in the southwestern part of the Pannonian basin system. Results are showing complex infilling patterns and changing base level throughout the time of progradation. Therefore, dating and palynological studies on well and outcrop data, will play a crucial role in solving the distribution of different paleoenvironments through space and time, thus confirming the interpretation of depositional system that is in such a way manifested on seismic data.

Acknowledgements

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Keywords: *Drava basin, clinoforms, Lake Pannon, delta, shelf progradation*

References

BALÁZS, A., MATENCO, 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., MAGYAR, I., MATENCO, L., SZTANÓ, O., TŐKÉS, L. & HORVÁTH, F. (2018): Morphology of a large paleolake: Analysis of compaction in the Miocene- Quaternary Pannonian Basin. Global and Planetary Change, 171, 134-147.

IVKOVIĆ, Ž., MATEJ, S. & ŠKOKO, M. (2000): Seismostratigraphic Interpretation of Upper Miocene and Pliocene Sediments of the Sava Depression. In: VLAHOVIĆ, I. & BIONDIĆ, R. (eds.): Proceedings of the Second Croatian Geological Congress, Cavtat, May 17-20, 2000, 219-222.

SAFTIĆ, B., VELIĆ, J., SZTANÓ, O., JUHÁSZ, GY. & IVKOVIĆ, Ž. (2003): Tertiary subsurface facies, source rocks and hydrocarbon reservoirs in the SW part of the Pannonian Basin (northern Croatia and south-western Hungary). Geologia Croatica, 56, 101-122.

SZTANÓ, O., SZAFIÁN, P., MAGYAR, I., HORÁNYI, A., BADA, G., HUGHES, D.W., HOYER, D.L. & WALLIS, R.J., (2013): Aggradation and progradation controlled clinothems and deep-water sand delivery model in the Neogene lake pannon, Makó Trough, Pannonian Basin, SE Hungary. Global and Planetary Change, 103, 149-167.

TOMLJENOVIĆ, B. & CSONTOS, L. (2001): Neogene-Quaternary structures in the border zone between Alps, Dinarides and Pannonian Basin (Hrvatsko zagorje and Karlovac Basins, Croatia). International Journal of Earth Sciences (Geologische Rundschau), 90, 560-578.

UHRIN, A. & SZTANÓ (2012): Water-level changes and their effect on deepwater sand accumulation in a lacustrine system: a case study from the Late Miocene of western Pannonian Basin, Hungary, 101, 1427-1440.

GPR Surveying in "Pećina u Dunjaku" Cave (Vojnić Municipality, Croatia)

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The Dunjak area is located in the transitional zone between the Dinaridic karst and the Peripannonian part of Croatia, and it is made of the Lower Triassic sedimentary rocks, dominated by silty sand and carbonates (limestone and dolomite). The most important underground karst form in this area is "Pećina u Dunjaku" cave, which represents the fossil karst conduit. The first known speleological research of this cave was carried out in 1972 by members of the Speleological Section of the Mountain Association "Dubovac", and they made the first topographic map of the cave (with total length of the cave 183 m) (PAIĆ, 2014) . The next documented researches followed in 1975 when members of the Speleological Section of the Mountaineering Society of the University "Velebit" made a new topographic map of the cave (with total length of cave 256 m). Paleontological research in the cave was carried out by Mirko Malez in 1988 (MALEZ et al., 1988). The members of the Speleological Club "Ursus spelaeus" and the Speleological Society of Karlovac, in the period from 2015 to 2017, made a new plan of the cave (with total length of the cave 257.5 m, height difference 11.8 m).

Within the systematic research of the speleogenesis of this cave, along with many other methods used, GPR surveying was performed with the MALÅ GX 450 MHz antenna. The MALÅ GX measuring system consists of two separate components: GX controllers and GX antennas connected via data cable. Geo positioning was not possible with the built-in DGPS due to the specificity of surveying (inside the cave), but surveyed profiles are linked on polygon that was made during the cave topographic surveying. GPR surveying was done in the final 70 meters of the main cave channel. Due to the specific morphology and dimensions of the cave channels, it was not possible to record perpendicular profiles, but all the profiles were measured in both directions in order to achieve better quality and gain more data, which enabled better processing and interpretation. Interpretation of the four horizons were performed by applying GPR facies recognition. The base of the method is adopted Neal´s chart (NEAL, 2004). For GPR facies defining, beside the signal shape, internal relationship, continuity and strength, the instantaneous attributes values were used to differ particular geo units (SLADOVIĆ et al., 2018) The differentiation of four GPR facies were enabled due to this approach. Among the most important research results are: (i) definition of the depth of the cave quaternary sediments (5-7 m), (ii) definition of the cave sediments composition (exchange of clastites and flowstone layers) and (iii) detection of groundwater level i,e. karst aquifer within quaternary sediments in the cave.

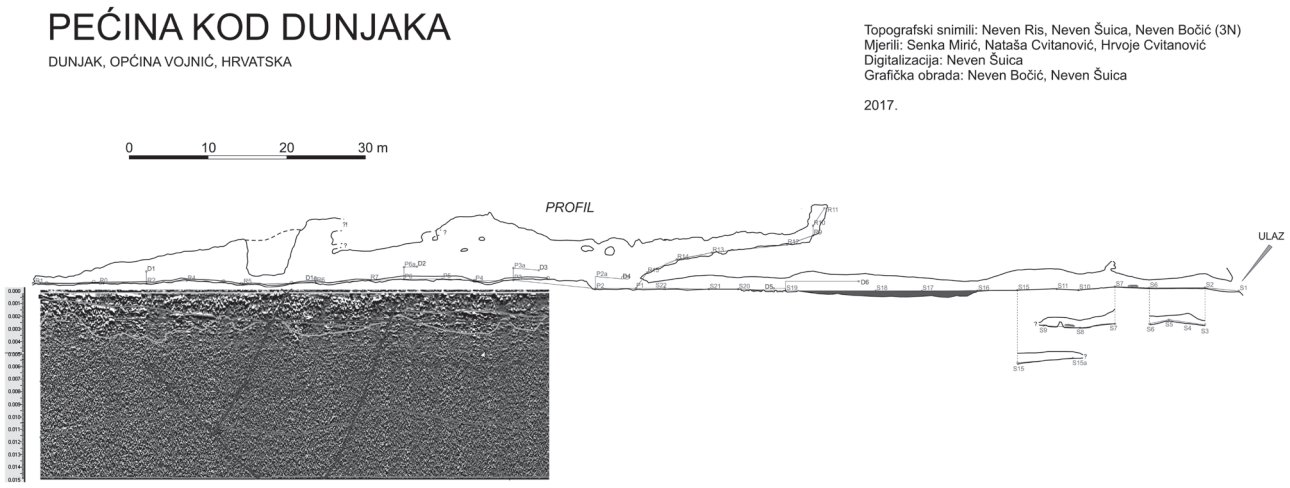

Figure 1. Cross-section of the main cave channel with part of the results of GPR surveying.

Acknowledgements

The research was carried out within the project: "Exploration of geomorphologic-geological conditions of glaciers and hydromorphological particularities at selected sites of the Dinaridic karst in Croatia", which was funded by University of Zagreb.

Keywords: karst, Ground penetrating radar, speleogenesis, Dunjak, Croatia

References

MALEZ, M., GARAŠIĆ, M. & KOVAČEVIĆ, T. (1988): Pećina kod Dunjaka na Kordunu kao primjer tipičnog medvjeđeg brloga u pleistocenu. Naš krš, 14/24-25, 129-137.

NEAL, A., (2004): Ground-penetrating radar and its use in sedimentology: principles, problems and progress. Earth-Science Reviews, 66, 261-330.

PAIĆ, M. (2014): Geomorfologija krša područja Dunjaka između Slunja i Vojnića (Karst Geomorphology of Dunjak Area between Slunj and Vojnić), Master Thesis, Faculty of Sience, University of Zagreb, 67 p.

SLADOVIĆ, Ž., MIKIĆ, Z. & KALAJŽIĆ, J. (2018): GPR facies determination – Pusto Brdo - Srebrnjak Hill's Recent and Historical Landslides. In: JEMECAUFLIČ, M., MIKOŠ, M. & VERBOVŠEK, T. (eds.): Advances in Landslide Research. Proceedings of the 3rd Regional Symposium on Landslides in the Adriatic Balkan Region, 11-13 October 2017, 47-51.

Petrology and Geochemistry of Appinite-Granodiorite Intrusion from the Eastern Drava Depression (Eastern Croatia)

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In the subsurface of the eastern Drava depression, a complex shallow intrusion occurs, which is composed of monzodiorite, granodiorite and hornblende diabase. Hornblende is one of the main mineral phases in mafic and intermediate rocks, which indicates unusually high water content in magma. Consequently, the mafic and intermediate rocks could be defined as appinites. Porphyritic hornblende diabase is composed of plagioclase and hornblende, with occurrence of sporadic biotite and quartz close to the contact with the granodiorite. Hypidiomorphic granular monzodiorite contains plagioclase, hornblende, orthoclase, quartz and biotite. Granodiorite with seriate

texture is composed of plagioclase, quartz, orthoclase and biotite, with hornblende that mostly appears near the contact with the hornblende diabase. Textural evidence points to magma mixing and mingling between mafic and felsic end members. The analyzed rocks belong to the calc-alkaline and high-K calc-alkaline series, and are characterized by high FeO_t contents relative to MgO.

Whole-rock primitive mantle-normalized trace element patterns commonly display Cs positive and Ba negative anomaly. Chondrite-normalized REE patterns are characterized by LREE enrichment relative to MREE and HREE. Trace element geochemistry points to a common lithospheric mantle source, metasomatized by subduction processes. Weak negative Eu anomalies are pronounced in the mafic and intermediate rocks, while granodiorite displays a positive Eu anomaly. These characteristics rule out plagioclase as a fractionating phase, and indicate the importance of hornblende in the evolution of the magma. Textural, mineralogical and geochemical characteristics of the analyzed rocks are clearly distinguishable from the Paleozoic magmatic rocks of the Slavonian mountains. They share common characteristics with Paleogene intrusive rocks of the subsurface of Zala basin in Hungary, which are considered as a continuation of Periadriatic intrusions to the northeast (BENEDEK et al., 2004).

Keywords: *appinite, granodiorite, magma mixing, Drava Depression*

References

BENEDEK, K., PECSKAY, Z., SZABO, CS., JOSVAI, J. & NEMETH, T. (2004): Paleogene igneous rocks in Zala basin (Western Hungary): link to the Paleogene magmatic activity along the Periadriatic lineament. Geologica Carpathica, 55, 43-50.

Petrology and Geochemistry of the A-Type Granites and Related Rocks in the Western Srijem Area (Eastern Croatia)

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Among many different lithological units, including different types of magmatic, metamorphic and sedimentary rocks, alkali feldspar granite, microgranite, alkali feldspar syenite and mylonitic gneiss are important constituents of the Neogene basement of the Western Srijem area (Eastern Croatia). These rocks belong to Upper Cretaceous bimodal magmatism of the Sava suture zone.

The magmatic rocks display similar mineral compositions – alkali feldspar granite is composed of perthite, quartz, albite, biotite and amphibole, microgranite contains antiperthite, perthite, quartz and albite, while the alkali feldspar syenite is composed of perthitic orthoclase and microcline, albite, quartz and amphibole. Mylonitic gneiss is composed of quartz, K-feldspar, plagioclase, biotite, muscovite and garnet. Zr-saturation temperatures of 830-850 °C and pressure values estimated by Al-in-hornblende geobarometer <2.5 kbar obtained for the alkali feldspar granite indicate shallow intrusive origin, which is in accordance with petrographic characteristics. A high $FeO_t/(MgO+FeO_t)$ ratio along with high contents of K_2O, Na_2O, REE^{3+}, Rb, Zr, Nb and Y, accompanied by low contents of CaO, MgO, P_2O_5, Ba, Sr and Eu in alkali feldspar granite suggest an A-type affinity. It is in accordance with the mineral chemistry of the ferromagnesian phases – annitic biotite showing clear alkaline affinity and ferro-edenite. The high Fe/(Fe+Mg) ratios of biotite and amphibole point to crystallization under low fO_2. Geochemical characteristics of the mylonitic gneiss indicate a protolith comparable to alkali-feldspar granite. Alkali feldspar syenite, otherwise similar to the alkali-feldspar granite, has no Eu anomaly in chondrite-normalized REE patterns, and is characterized by positive K and Zr anomalies in primitive mantle-normalized trace element patterns. These observations indicate a cumulate origin for the alkali-feldspar syenite. The microgranite, on the other hand, has low K_2O and Rb contents and high Na_2O and Sr contents compared to the alkali feldspar granite. This could be explained by magma separation during its late stage of evolution, which was controlled by crystallization of K-feldspar and biotite.

The overall evolution of the magma is controlled by fractional crystallization. Partial melting was followed by

fast magma ascent to shallow levels (about 8 km deep). A-type magmatism is related to extensional tectonics, indicating an Upper Cretaceous extensional event probably located in the continental crust. A possible geodynamic setting is a fore-arc basin located on the upper European plate.

Keywords: *A-type magmatism, Neogene basement, Sava Suture Zone*

Petrographic Characteristics of the Appinite-Granodiorite Intrusion, Eastern Drava Depression (Eastern Croatia)

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The appinite-granodiorite shallow intrusive body is characterized by complex textural relationships between different types of rocks. The shallower part of the hypabyssal body is composed mainly of granodiorite with hornblende diabase enclaves, while the deeper part is made up of intermediate lithology – monzodiorite. The monzodiorite is characterized by a fine-grained, hypidimorphic granular, locally porphyritic and poikilitic textures. It is composed of plagioclase, hornblende, orthoclase, quartz, biotite, accessory opaques, apatite and zircon. The hornblende diabase is porphyritic with phenocrysts of plagioclase and hornblende set in a finer groundmass composed of plagioclase, hornblende, accessory opaques, apatite and zircon, while biotite, quartz and orthoclase are situated near the contact with the granodiorite. The granodiorite exhibits a seriate texture and is composed of plagioclase, quartz, orthoclase and biotite, with accessory opaques, apatite and zircon.

Hornblende occurs near the contact with the hornblende diabase. Enclaves in the shallow part are ~1-10 cm long and are very diverse, having different shapes and contact sharpness with the host rock. Angular enclaves with sharp contacts with host rocks indicate intrusion of mafic magma at an advanced stage of crystallization, while ellipsoid enclaves with sharp contacts point to intrusion of liquid mafic magma. Ameboid-shaped enclaves with diffuse contacts are characterized by the occurrence of a hybrid lithology and indicate low temperatures and viscosity gradients between the mafic and felsic end members. The different types of enclaves point to complex and long-term processes involving the interplay of the two end-member magmas.

The monzodiorite in the deeper parts of the body most likely represents a hybrid lithology. Textural characteristics of this rock, such as the occurrence of sieve-textured plagioclase and acicular apatite point to dynamic setting and unsteady conditions in magma chamber. The lower liquidus temperature of the water-rich mafic magma probably enhanced the process of mixing between hot mafic and colder felsic end members.

Mixing processes dominated the deeper part of the chamber, while in the shallower part mingling processes prevailed.

Keywords: *hornblende diabase, monzodiorite, granodiorite, magma mixing, magma mingling*

New Lithosphere Model of the Dinarides Based on the Forward Teleseismic Modelling

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For a long time some considerations about a subduction of the Adriatic microplate beneath the Dinarides have been introduced. The Adriatic subduction in the geological history was documented in the literature, which took part from the Jurassic to the Paleogene. But, the absence of a lithospheric slab or "slab gap" has been considered in recent geological models, at least beneath the northern Dinarides (HANDY et al., 2015), based on some regional and global tomographic models (KOULAKOV et al., 2009) that pointed to a lack of the fast velocity anomaly beneath the northern Dinarides. However, new velocity models have revealed existence of shallow fast velocity anomaly in the northern Dinarides and deep fast anomaly in the southern Dinarides (ŠUMANOVAC & DUDJAK, 2016; ŠUMANOVAC et al., 2017). The anomaly was interpreted as a separation of the lower Adriatic lithosphere, which is detached from the crust, and steeply sinks beneath the Dinarides.

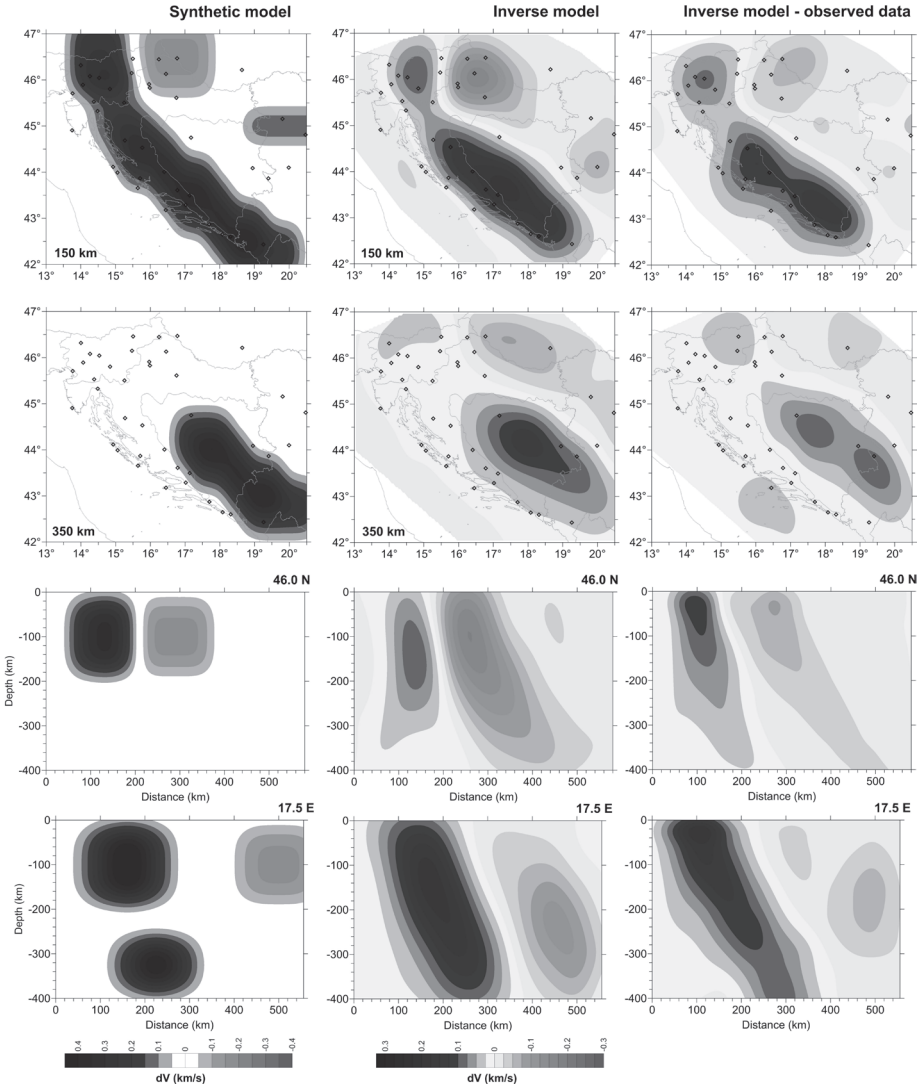

Figure 1. Forward modelling of lithospheric slabs beneath the Dinarides. Horizontal sections extracted from the 3-D velocity model in the upper part, and vertical sections in the lower part. Comparison of inverse models for synthetic and observed data shows there is no break of the shallow Adriatic slab in the northern Dinarides, but the deep southern Adriatic slab consists of two parts.

A lithospheric slab sinking in the asthenosphere can be efficiently discovered by teleseismic tomography based on a fast velocity anomaly. The method has a good horizontal and a poor vertical resolution. However, good horizontal resolution depends on the space sampling, which means the study area should be uniformly covered by the receivers. Seismic arrays applied in the Koulakov and some other models do not satisfy this requirement. The study area was much better sampled by the array applied by ŠUMANOVAC et al., (2017) and significantly higher resolution has been achieved.

The forward seismic modelling in the area of Dinari- des has been applied to improve a reliability of the interpretation. A set of synthetic models was constructed and obtained inverse models were compared with the inverse model for observed data published by ŠUMANOVAC et al. (2017). In this model the shallow fast anomaly beneath the northern Dinarides clearly points to shallow descending Adriatic slab, but there are also

several problems in the interpretation of the fast anomaly. The deep fast anomaly in the model (up to 450 km) in the southern Dinarides could not be unambiguously interpreted, because of the poor vertical resolution of the method, and the fast shallow anomaly is partially attenuated in the area of the northern Dinarides and gives an impression about the break in the lithospheric slab between the northern and southern Dinarides.

Based on the seismic modelling, the analysis has showed the shallow Adriatic lithospheric slab stretches continuously beneath the entire Dinaridic mountain range (Fig. 1). The shallow Adriatic lithospheric slab in the northern Dinarides has been validated, but a cause of the deep southern fast anomaly does not have to be continuous deep Adriatic slab. A better fit of synthetic and observed inverse models has been obtained if the southern Adriatic slab has been considered as a discontinuous lithospheric slab, which consists of two parts. Accordingly, new geological model of the southern Dinarides has been constructed. Considering geological development a conclusion can be drawn the shallow Adriatic slab, stretching beneath the entire Dinaridic mountain range, is a consequence of the recent Adriatic subduction, and the deep part of the Adriatic slab in the southern Dinarides could be remnants of an older Adriatic subduction.

Keywords: *Dinarides, subduction, lithosphere model, seismic modelling*

References

HANDY, M.R., USTASZEWSKI, K. & KISSLING, E. (2015): Reconstructing the Alps-Carpathians-Dinarides as a key to understanding switches in subduction polarity, slab gaps and surface motion. Int. J. Earth Sci., 404/1, 1-26.

KOULAKOV, I., KABAN, M.K. & TESAURO, M. (2009): P- and S-velocity anomalies in the upper mantle beneath Europe from tomographic inversion of ISC data. Geophysical Journal International, 179, 345-366.

ŠUMANOVAC, F. & DUDJAK, D. (2016): Descending lithosphere slab beneath the Northwest Dinarides from teleseismic tomography. Journal of Geodynamics, 102, 171-184.

ŠUMANOVAC, F., MARKUŠIĆ, S., ENGELSFELD, T., JURKOVIĆ, K. & OREŠKOVIĆ, J. (2017): Shallow and deep lithosphere slabs beneath the Dinarides from teleseismic tomography as the result of the Adriatic lithosphere downwelling. Tectonophysics, 712-713, 523-541.

Magnetotelluric Method (CSAMT) in the Exploration of Deep Hydrogeological Targets

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A groundwater research cannot be imaged today without application of the electrical resistivity tomography (ERT), especially in the areas that are characterised by very complex geological models. The method can be even considered as a fundamental geophysical method, especially in karst areas. However, there is a serious limitation of the method in the groundwater exploration. Namely, standard equipment for ERT is declared to reach target depths up to 130 m. The problem is even greater because the effective (real) depth penetration is in the range 70-100 m, depending on the resistivity relationships at the interface. Experience has shown that in most terrains the real depth penetration is 70-80 m. On the other hand, deeper hydrogeological investigations seek depth penetration of several hundred meters. In such cases the use of Controlled Source Audio Magnetotelluric (CSAMT) can solve the problem (ŠUMANOVAC & OREŠKOVIĆ, 2018).

The capabilities of CSAMT method are analysed on the exploration case study in the Apatovec area. The study area is characterised by the complex geological relationships. According to the previous studies and surface geological data, the study area is covered by Quaternary sediments, Miocene rocks (Pontian, Pannonian and Badenian), Oligo-Miocene rocks, Cretaceous sediments and diabase. There is a wide range of permeable and impermeable clastic and carbonate rocks, which can be determined on the basis of different resistivities.

Field measurements were performed by Stratagem EH4 system that allows frequencies up to 10 kHz to be recorded. The investigation depth depends on frequency and subsurface resistivity, so the depths between 500 m and 1000 m can be reached. Electrical field components (*Ex*, *Ey*) were measured on two perpendicular dipoles and two horizontal magnetic field components (*Hx*, *Hy*) were measured using induction coils. The surface impedance (*Z*) at a measurement site is calculated in two orthogonal directions and the apparent resistivity and phase are calculated from impedance components (*Zxy* and *Zyx)* The

CSAMT data were recorded along profiles on MT-sounding stations with distances between stations from 15 to 50 m. The CSAMT data recorded along profiles were interpreted to obtain resistivity models that reflect subsurface geology in two ways, using inverse 2D modelling and forward 1D modelling (Fig. 1). We have employed an Occam's inversion (DE GROOT-HEDLIN & CONSTABLE, 1990), with use of smoothing operator and additional contrast minimization to obtain simple and rather smooth resistivity model.

The inverse resistivity model shows small resistivities, pointing to the impermeable rocks, at the surface and large resistivities, indicating permeable rocks, at greater depth (Fig. 1). But, the thickness of the low resistivity body is small (up to 40 m) at the beginning of the profile, and large (around 200 m) on the other part of the profile. The high resistivity body at the beginning of the profile probably consists of several high resistivity bodies and shallowest one is caused by the permeable Badenian rocks. The shape of high resistivity body points to reverse fault at the position of MT-4 station, which is also determined by the geological mapping. The 1D resistivity models can assist to define the interface of the high resistivity body.

This study, but also many other exploration cases show that the CSAMT method provides the most complete data on lithological and structural relationships if deep hydrogeological targets should be reached (deeper than 100 m). It can reach targets at larger depths with dense space sampling at significantly lower costs. The CSAMT method provides information on the existence of aquifers and their general burial depths. The interpretation of CSAMT data is much more complex in relation to resistivity methods. More reliable models are obtained by the application of both, forward and inverse modelling since the interpretation is under the control of interpreter.

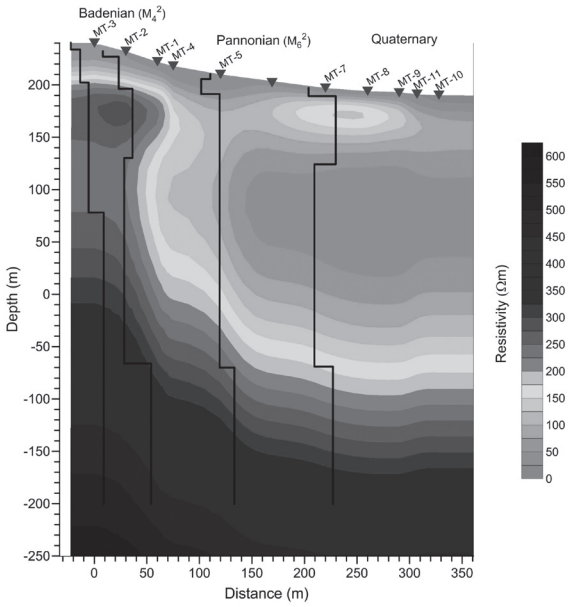

Figure 1. Inverse resistivity model of CSAMT data in the Apatovec area. Positions of the MT sounding stations are marked by triangles, and interpreted 1D data of selected MT stations are shown by step diagrams.

Keywords: *CSAMT, electrical resistivity tomography, groundwater, Apatovec*

References

DE GROOT-HEDLIN, C. & CONSTABLE, S. (1990): Occam's inversion to generate smooth, two-dimensional models from magnetotelluric data. Geophysics, 55, 1613-1624.

ŠUMANOVAC, F. & OREŠKOVIĆ, J. (2018): Exploration of buried carbonate aquifers by the inverse and forward modelling of the Controlled Source Audio-Magnetotelluric data. Journal of Applied Geophysics, 153, 47-63.

Paleogene Basins in Croatia as a Connection Between Tisza and Dinarides – A Missing Link

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There are many scientific and technical papers describing the relationship between Tisza and the Dinarides that are based on tentative interpretations of the subsurface geology since the contact between them is not visible at the surface (LUŽAR et al, 2012, PAMIĆ, 2002, and other). The "Sava suture zone" passes through the Sava basin and

it is considered to be a border between Tisza and Dinarides units. The only key to understanding the subsurface is deep exploration drilling. INA has been exploring the Sava basin for the past 50 years. Therefore, there is a vast archive of various analytics performed on cores and drilling cuttings and biostratigraphic, petrographic, geochemical and fluid analyses that need to be viewed in light of recent regional geological findings.

The Dinarides structural unit is clearly visible in outcrops from Karlovac in the west, Banja Luka in the central part, all through Tuzla and furthermore to the east. Paleogene-Neogene sediments lie due north regarding the "Sava suture zone" and extend all the way to the Sava river. North of Sava river there are mostly Quaternary sediments lying over Neogene sediments that are positioned on the older formations of Tisza. The direct contact of the Dinarides unit with Tisza remains unknown. Although Paleogene basins were well developed in the area of northern Bosnia, their development and extent in the Croatian part of the Pannonian basin remains a mystery. Certain wells in the southernmost part of the Pannonian basin, in the area of the Karlovac sub-basin, encountered Paleogene sediments. The official lithostratigraphic nomenclature of INA never included Paleogene lithostratigraphic unit as it was considered to be a part of the Prečec formation that has remained undivided for decades and as such received a status of a complex. As a result of such division, geological events that took place between 65 and 20 Ma years ago were insufficiently explored and never fully understood. Furthermore, the majority of metasediments, potentially of Paleogene age, were marked with EL marker Tg (Basement) which allocated them into older geological formations. The latest research and analyses completed in the past 5 years has resulted in undeniable proof of the existence of Paleogene sediments in the southern parts of the Pannonian basin, in the northern Posavina zone. 2D and 3D seismic show geological units that can be correlated and calibrated with Paleogene sediments.

2D and 3D seismic, as do many other analytical methods, have their limitations and interpretation of such data can be different from author to author resulting in different theses. 3D seismic in the western part of the Sava basin, along with laboratory analyses, can shed light on the distribution, extent and development of Paleogene sediments in the northern Posavina area. Paleogene basins represent a missing link between the Dinarides and Tisza units and are a crucial element in the interpretation of geological events that took place between 65 and 20 Ma years ago.

Keywords: *Paleogene basins, Tisza, Dinarides, Sava Suture Zone, Pannonian Basin*

References

LUŽAR-OBERITER, B., MIKES, T., DUNKL, I., BABIĆ, LJ., EYNATTEN, H. (2012): Provenance of Cretaceous synorogenic sediments from the NW Dinarides (Croatia). Swiss J.Geosci., 105, 377-399.

PAMIĆ, J. (2002): The Sava-Vardar Zone of the Dinarides and Hellenides versus the Vardar Ocean. Eclogae Geol.Helv., 95, 99-113.

USTASZEWSKI, K., HERAK, M., TOMLJENOVIĆ, B., HERAK, D., MATEJ, S. (2014): Neotectonics of the Dinarides–Pannonian Basin transition and possible earthquake sources in the Banja Luka epicentral area. J.Geodyn., 82, 52-68.

Hydrogeological Research for Establishment of Transboundary Sanitary Protection Zones – Prud Spring Case Study

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During the 2019 a research program was done to establish sanitary protection zones (SPZ) of important karst spring Prud. The spring is situated in southern Dalmatia, on the edge of the Neretva River valley near the town Metković, Croatia. Water from this spring is used for the water supply of parts of Metković and its surrounding settlements; and for large water supply system NPKL (Neretva River – Pelješac Peninsula – Korčula Island – Lastovo Island). Since most of the spring's catchment area spreads in neighboring Bosnia and Herzegovina (B&H), the research has to be done on transnational level. Therefore, Croatian waters established a research program in which Croatian

geological survey will provide necessary data in Croatian part of the catchment, according to Croatian regulations; while company Integra d.o.o. will do the same from the B&H side. After finishing national reports, a single proposition/report of the SPZ will be sent to responsible authorities from both countries. This will be the first case of such transboundary groundwater protection in this part of the Dinaric karst.

Prud spring is a typical karst spring. Its catchment area is very large, but most of it is "shared" with several springs and karst rivers. Among those, the most important rivers are Lištica and Trebižat, while most important karst springs that share parts of the catchment area with Prud are: Borak, Vrioštica, Klokun (B&H), Opačac, Butina, Klokun (Croatia), and Mandina mlinica. Croatian part of the catchment is divided into two areas – one near Imotski, from where surface and groundwater flow into the B&H, and second one in the Prud Spring vicinity. B&H part of the catchment is quite large going up to the Rakitno karts polje. Springing zone from Prud to Mandina mlinica is a final step of large and mutually interconnected set of karst sub-catchments, and delineation of those was most important task.

The data from previous, published or unpublished researches was considered, and since several water supply springs within this region already had established SPZs, those areas were excluded from the Prud spring SPZ final report.

Keywords: *karst, hydrogeology, hydrology, sanitary protection, transboundary water management, hydrochemistry*

Protection of Drinking Water Resources Through Integrated Land-Use Management Approach

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Land-use practices can be considered as one of the main factors that impact and modify hydrological and hydrogeological systems, therefore affecting the quality and quantity of drinking water resources. Throughout Interreg Danube project CAMARO-D (Cooperating towards Advanced MAnagement ROutines for land use impacts on the water regime in the Danube river basin) and Interreg Central Europe project PROLINE-CE (Efficient Practices and Land Use Management Integrating Water Resources Protection and Non-structural Flood Mitigation Experiences) interdisciplinary approach is fostered with the intention of investigating intricate relations and impacts of land-use activities, climate changes and floods on drinking water resources. Transnational project partnership is comprised of research institutions covering a broad spectrum of affiliation, such as foresters, agronomists, hydrogeologists, spatial planners and ministries in order to address the common environmental issues in synergic manner.

Drinking water resources in Croatia, generally considered being of good quality and quantity, are coming use increasing pressure due to improper land-use activities, climate changes and certain deficiencies in management (HRVATSKE VODE, 2016). As a response, within CAMARO-D and PROLINE-CE, specific areas are chosen for further investigation: (i) karstic part of Kupa River catchment and (ii) parts of South Dalmatia (from the Imotsko polje to discharge zone: Prud-Klokun-Mandina mlinica springs). Investigated areas are characterized by karst topography, with very complex hydrogeological forms and features, such as poljes, ponors, estavelles and preferential groundwater flow paths (LUKAČ REBERSKI et al., 2016). Aquifers in such karst terrains usually have high intrinsic vulnerability due to the lack of overlaying layers.

In investigated areas the quality and quantity of drinking water resources is at risk due to impacts of adverse seasonal floods, hydrotechnical objects which have strongly modified hydrological systems and water regime, inadequate land-use practices and unfavourable climate change scenarios which point out to changes in trends of precipitation, temperature and discharge in near future. Locally, other issues include intensive agricultural activity in terms of plant protection products over-use (Fig. 1.), high losses in water supply systems, illegal waste dumps, and inadequate collection and treatment of wastewaters (TERZIĆ & FRANGEN, 2017).

In attempt to identify negative impacts of various types of land use, as well as to improve understanding of hydrogeological and hydrological processes in investigated

Figure 1. Neretva valley – landscape significantly modified by land use activities, meliorative actions and hydropower production, leading to changes in the water regime and related ecosystems.

areas, *in situ* measurements of physio-chemical parameters and hydrochemical laboratory analyses were conducted on spring and surface water. Hydrological modelling of possible impacts of climate change on water resources was carried in the scope of CAMARO-D and PROLINE-CE. Correlation and comparison of measured (historical 1961-1990 and recent 1981-2010) and modelled data for 30 year reference period (2041-2070) pointed out how hydrological regime of both investigated areas is going to experience decreased discharge, more frequent extreme events and significant increase in temperature (HORVAT & RUBINIĆ, 2003 & 2006). Additionally, in the scope of CAMARO-D, a comprehensive vulnerability assessment was carried out with the help of GIS tools, by compiling and overlapping layers of natural (intrinsic) vulnerability and potential hazards of anthropogenic origin. The vulnerability and hazard assessment were based on good practices of previously renowned methods, especially recommendations of European COST 620 project. As protection against floods is one of the main CAMARO-D objectives, hazard map was further overlapped with flood risk map (MAYER et al., 2019).

With main gaps and conflicts between land use and water management being recognized, best management practices for drinking water protection are derived in order to achieve function-oriented land use-based spatial management at the operational level. Proposed best management practices are integral part of two major outputs of the projects, namely GUIDR (Guidance for the Danube Region for sustainable land use planning) in CAMARO-D and DriFLU (Drinking Water/Floods/Land use) Charta in PROLINE-CE.

Keywords: land-use management, best management practices, PROLINE-CE, CAMARO-D, drinking water resources

References

HRVATSKE VODE (2016): Plan upravljanja vodnim područjima 2016-2021 (River basin management plan 2016-2021), 87-89

HORVAT, B. & RUBINIĆ, J. (2003): Primjena GIS-a na procjenu otjecanja (GIS Application in Surface Runoff Estimation), Proc. 3rd Croatian Conference on Waters, 265-271, Osijek, Croatia.

HORVAT, B. & RUBINIĆ, J. (2006): Annual runoff estimate - an example of karstic aquifers in the transboundary region of Croatia and Slovenia, Hydrological Sciences Journal, 51(2). 314-324.

LUKAČ REBERSKI, J., TERZIĆ, J., FILIPOVIĆ, M., FRANGEN, T. & MARKOVIĆ, T. (2016): Impact of land use on groundwater quality in south Dalmatia test area. In: International Symposium – DRINKADRIA Cross-border drinking water management, Rijeka, 29th Jan 2016; Book of proceedings, 153-167.

MAYER, R., BLANZANO, K., MAYER, V., SCHROMMER, G. & GERHARDT, E. (2019): CAMARO-D Project brochure, HBFLA Raumberg-Gumpenstein, Irdning-Donnersbachtal, 2019.

TERZIĆ, J. & FRANGEN, T. (2017): Hydrogeological overview of the south Dalmatian dinaric karst catchment system (Karst Spring prud and Baćina Lakes), Stop 1&3: Karst spring Prud and Baćina Lakes. Excursion guidebook, 44th annual congress of the INTERNATIONAL ASSOCIATION OF HYDROGEOLOGISTS, Dubrovnik, Croatia, 25th - 29th September 2017.

REEBAUX – Prospects of REE Recovery From Bauxite and Bauxite Residue in the ESEE Region

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A large number of bauxite deposits and a long history of aluminium industry in the ESEE region triggered many professional and scientific studies in respect of recovery of CRM (critical raw materials) from bauxite and bauxite residue, which is produced in Bayer process of alumina production. So far, several projects have been proposed and executed in the European scale, dealing with extraction of REE from bauxite-related resources in particular. Bauxite residue (red mud) in many cases showed REE concentrations at least doubled relative to those in parent bauxites (DEADY et al., 2014). REE as a group of elements are listed among other CRM due to their high demand in many modern industrial applications. They have been proved to be deficient in Europe due to a lack of their production from domestic REE resources. Thus, REE supply largely relies on imports outside Europe. Many studies have been lunched in order to develop and introduce production of REE for the European market from various REE-enriched deposits (GOODENOUGH et al., 2016). Different methods to recover REE from bauxite residue have been tested, including leaching with various acids, and recent introduction of functional ionic liquids particularly showed promising results (DAVRIS et al., 2018).

In scope of the REEBAUX project, bauxite-related resources in the partner countries (Austria, Croatia, Hungary, Montenegro and Slovenia) are evaluated for their potential use in REE recovery, and viable extraction methods for their production thereof are expected to be assessed. The project activities are organized as three independent yet mutually connected workpackages, which include assessment of REE potential in the most perspective bauxite deposits in the region as well as in a few available red mud accumulations. In addition, a set of activities aiming at strengthening a relationship to local stakeholders and improving regional innovation capacity in bauxite exploration and REE recovery technologies is a part of the project agenda.

Acknowledgements

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Keywords: *bauxite, bauxite residue, REE, ESEE region*

References

DAVRIS, P., BALOMENOS, E., PANIAS, D. & PASPALIARIS, I. (2018): Developing new process for selective extraction of rare earth elements from bauxite residue based on functional ionic liquids. In: MARTIN, O. (ed.): Light Metals 2018, The Minerals, Metals & Materials Series, The Minerals, Metals & Materials Society. Springer, 149-156.

DEADY, É., MOUCHOS, E., GOODENOUGH, K., WILLIAMSON, B. & WALL, F. (2014): Rare earth elements in karst-bauxites: a novel untapped European resource? ERES2014 – 1st European Rare Earth Resources Conference, 4-7 September, 2014, Milos, 1-12.

GOODENOUGH, K.M., SCHILLINGB, J., JONSSON, E., KALVIGE, P., CHARLES, N., TUDURI, J., DEADY, E.A., SADEGHI, M., SCHIELLERUP, H., MÜLLER, A., BERTRANDF, G., ARVANITIDIS, N., ELIOPOULOS, D.G., SHAWG, R.A. & THRANE, K. (2016): Europe's rare earth element resource potential: An overview of REE metallogenetic provinces and their geodynamic setting. Ore Geol Rev, 72, 838-856.

Structure and Tectonic Evolution of the Velebit Mt. in the Central Part of the External Dinarides

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Detailed outcrop-scale analysis of fault-slip data, in combination with data presented on published geological maps, were used for a reconstruction of the structural architecture and tectonic evolution of the Velebit Mt., the most prominent geomorphological structure in the central part of the External Dinarides in Croatia. The analysis of kinematic indicators recorded by major fault planes indicates the prevalence of dip-slip and top-to-NE motions, verifying that these faults are NE-verging thrusts rather than NE-dipping normal faults as previously thought. Consequently, we challenge earlier tectonic models that interpret the Velebit Mt. structure as a SW-vergent antiformal stack or thrust duplex formed above the major NE-dipping thrust system (TARI KOVAČIĆ & MRINJEK, 1994) or as a complex transpressional structure formed during the late-orogenic escape tectonic phase along an inherited crustal fault zone (GRANDIĆ et al., 2004; KORBAR, 2009). Instead, we use the concept of a passive roof duplex within a triangle structure. Thereby, the Velebit structure represents a stack of NE-verging backthrusts formed above a SW-vergent compressional duplex. Our interpretation was recently tested by BALLING et al. (2017) by construction of forward modelled balanced cross sections.

Additionally, we analysed a large set of fault-slip data comprising more than 1000 measurements collected in the carbonate breccia exposed along the SW mountain slope at about 60 measurement sites. Curiously, the majority of recorded fault-slip data comprise structures with a normal sense of shear indicating orogen-perpendicular (NE-SW) to orogen-parallel (NW-SE) extension. According to the very good preservation and high frequency of occurrence, these extensional structures may have played an important role in formation of the extremely voluminous carbonate breccia exposed along the SW mountain slope. Accordingly, we propose that these structures resulted from a state of stress characterised by radial extension induced by gravitational collapse and spreading as a result of the uptilting of the SW-dipping Velebit monocline. Therefore, our interpretation is only partly in accordance with KORBAR (2009) who suggested that divergent extension and gravity gliding was a major mechanism in formation of the carbonate Jelar breccia in general.

Acknowledgements

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Keywords: *Velebit Mt., External Dinarides, passive roof duplex*

References

BALLING, P., TOMLJENOVIĆ, B., SCHMID, S. & USTASZEWSKI, K. (2017): Contrasting deformation styles across the Split-Karlovac Fault (External Dinarides) induced by reactivation of pre-existing structures. In: ŠARIĆ, K., PRELEVIĆ, D., SUDAR, M. & CVETKOVIĆ, V. (eds.): 13th Workshop on Alpine Geological Studies, Abstracts, Uni. Belgrade, Belgrade.

GRANDIĆ, S., KRATKOVIĆ, I., KOLBAH, S. & SAMARŽIJA, J. (2004): Hydrocarbon potential of stratigraphic and structural traps of the Ravni Kotari area – Croatia. NAFTA, 55, 7-8, 311-327.

KORBAR, T. (2009): Orogenic evolution of the External Dinarides in the NE Adriatic region: a model constrained by tectonostratigraphy of Upper Cretaceous to Paleogene carbonates. Earth Science Reviews, 96/4, 296-312.

TARI KOVAČIĆ, V. & MRINJEK, E. (1994): The Role of Palaeogene Clastics in the Tectonic Interpretation of Norhtern Dalmatia (Southern Croatia). Geologia Croatica, 47/1, 127-138.

Determination of Hydraulic Properties of Porous Media from Hydrogeological Aspect

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Hydraulic properties of porous media are researched for different purposes – in pedological, hydrogeological, oil engineering, various technological and other expertises.

In soil science, pedotransfer functions (PTF) are predictive functions of certain soil properties using data from soil surveys (BOUMA, 1989). Pedotransfer functions add value to this basic information by translating them into estimates of other more laborious and expensively determined soil properties. These functions fill the gap between the available soil data and the properties which are more useful or required for a particular model or quality assessment. PTF-s utilize various regression analysis and data mining techniques to extract rules associating basic soil properties with more difficult to measure properties. Also, it is important to emphasize that PTF-s define the fluid flow through the soil.

On the other hand, hydrogeological and similar researches of porous media are pointed in the direction of determining both the flow process and reservoir capacity of either shallow or deep deposits. In oil engineering, hydrodynamic measurements, probe tests and well logging methods are used. In hydrogeology, hydraulic properties are determined through analyses of pumping tests, slug tests and indirectly through the analyses of particle size distribution (PSD) data.

A pumping test (KRUSEMAN & DE RIDDER, 1990) is a field experiment in which a well is pumped at a controlled rate and water-level response is measured in one or more surrounding observation wells and optionally in the pumped well itself; response data from pumping tests are used to estimate the hydraulic properties of aquifers. A slug test is a particular type of aquifer test where water is quickly added or removed from a groundwater well, and the change in hydraulic head is monitored through time, to determine the near-well aquifer characteristics. On the other hand, properties of natural non coherent deposits greatly depend on granulometric compound and consolidation of material. These facts cause the fact that physical parameters that govern fluid flow through the pores can be identified from granulometric compound (URUMOVIĆ & URUMOVIĆ, 2017). Diverse methods were developed for purpose of calculating hydraulic properties of material from PSD data.

Here we will present some frequently used methods for calculation of hydraulic properties from PSD data and correlate the results with results of other hydrogeological and pedological methods.

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Keywords: *hydraulic conductivity, pumping test, grain size, theory and practice, HRZZ*

References

BOUMA, J. (1989). Using soil survey data for quantitative land evaluation. Advances in Soil Science. 9: 177–213

KRUSEMAN, G.P.; DE RIDDER, N.A. (1990). Analysis and Evaluation of Pumping Test Data (PDF) (Second ed.). Wageningen, The Netherlands: International Institute for Land Reclamation and Improvement. ISBN 90-70754-20-7

URUMOVIĆ, K. & URUMOVIĆ, K (2017). Validity and range of experimental and theoretical methods for identification of hydrogeological parameters from grain size data. Rudarsko-geološki glasnik 21, 1; 83-104

Diagenetic Processes and Reservoir Quality of the Cretaceous Sandstones From ANH-CR-Montecarlo-1X Well (400-1100 Ft.), Cesar-Ranchería Basin, Colombia

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In Colombia, the Cesar-Ranchería basin is a current prospective area of exploration for unconventional deposits (NATIONAL HYDROCARBON AGENCY, 2019). Estimates made by the National Hydrocarbon Agency and the Ministry of Mines and Energy, until 2018 forecast that the country's oil and gas reserves will last for 6.2 and 9.8 years respectively (MINISTRY OF MINES AND ENERGY, 2019).

Due to this hydrocarbon industry growing demand, it is increasingly necessary to search for precise and reliable techniques when evaluating a conventional and non-conventional oil system and one of its main axes the reservoirs rocks. In this way, the integral evaluation, including precise analysis of processes, spatial distribution and physical properties of hydrocarbon reservoirs, which have become one of the main focuses of exploration (YU et al., 2018). Several analytical techniques have been used in the evaluation of rock reservoirs, which include thin section microscopy (e.g., SANDOVAL, 2000; GUZMÁN et al., 2010; GUACANEME, 2011; RAHMAN & MCCANN, 2012; MONTEALEGRE et al., 2013; MOORE, 2013; LAI et al., 2016; KAREEM et al., 2017, LIMARINO et al., 2017, MA et al., 2018; MAHMIC et al., 2018), scanning electron microscopy (e.g., RAHMAN & MCCANN, 2012; KAREEM et al., 2017; LIMARINO et al., 2017; MA et al., 2018; MAHMIC et al., 2018) and basic petrophysics analysis (GUACANEME, 2011; LAI et al., 2016; YUAN et al., 2017).

Through petrography, diagenetic evolution processes can be identified (MOORE, 2013). The processes of destruction, formation, nature and distribution of the porosities and permeabilities are analyzed, which are evidence of the diagenetic history in the subsoil, also important since each diagenetic feature produced during the burying and lifting of a rock originally porous and permeable, affects its quality as a reservoir rock (SANDOVAL, 2000). In addition to conventional petrography, other analysis or techniques used in the reconstruction study of the post-depositional geological history, including the determination of the authigenic mineralogical composition are, among others, scanning electron microscopy analysis, determining the morphology of the pores and their distribution identifying the types of clay structures. Also, qualitative elementary analysis can be done with the EDAX probe when the morphology of the mineral is not distinguished, identifying the clay mineral fractions (that usually originate during diagenesis and occlude the porosity or occupy the interstitial spaces).

The results include petrographic and diagenetic analysis of more than 30 thin sections; analysis was performed establishing the main diagenetic products, taking into account aspects such as interstitial space transformations (analyzing the level of porosity and compaction), mineral neoformations distinguishing minerals from the group of clays that cover the grains of the framework, and other types of precipitates of cements such as silica, ferrous carbonate and non-ferrous, some of these present partial and/or total dissolution, for which secondary porosity is recognized, also metasomatisms, where processes of chloritization and illitization of the argillaceous matrix are observed, alteration of feldspars to ferrous and non-ferrous carbonate, which affects the porosity and permeability of the rock and component transformations.

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Keywords: diagenesis, Cesar-Ranchería basin, ANH-CR--Montecarlo-1X well, SEM, petrography

References

GUACANEME, C. (2011): Petrografía y Diagénesis a partir de Núcleos de Perforación de las Rocas Sedimentarias de la Cuenca San Juán, Chocó. Universidad de Caldas. Tesis de Pregrado, 116 p.

GUZMÁN, W., GARCÍA, A. & CARDONA, C. (2010): Estudio Petrográfico y Diagenético de la Secuencia Cenozoica del Cinturón Plegado de San Jacinto y su Aplicación en la Determinación de la Calidad de Reservorios. Ingeniería Investigación y Desarrollo, 10(2), 107-127.

KAREEM, R., CUBILLAS, P., GLUYAS, J., BOWEN, L. & GREENWELL, H.CH. (2017): Multi-technique approach to the petrophysical characterization of Berea sandstone core plugs (Cleveland Quarries, USA). Journal of Petroleum Science and Engineering, 149, 436-455.

LAI, J., WANG, G., RAN, Y., ZHOU, Z. & CUI, Y. (2016): Impact of diagenesis on the reservoir quality of tight oil sandstones: The case of Upper Triassic Yanchang Formation Chang 7 oil layers in Ordos Basin, China. Journal of Petroleum Science and Engineering, 145, 54-65.

References

LIMARINO, C.O., GIORDANO, S.R., & ALBERTANI, R.J.R. (2017): Diagenetic model of the Bajo Barreal formation (Cretaceous) in the southwestern flank of the Golfo de San Jorge Basin (Patagonia, Argentina). Marine and Petroleum Geology, 88, 907-931.

MA, P., LIN, C., ZHANG, S., DONG, C., ZHAO, Y., DONG, D. & MU, X. (2018): Diagenetic history and reservoir quality of tight sandstones: A case study from Shiqianfeng sandstones in upper Permian of Dongpu Depression, Bohai Bay Basin, eastern China. Marine and Petroleum Geology, 89, 280-299.

MAHMIC, O., DYPVIK, H. & HAMMER, E: (2018): Diagenetic influence on reservoir quality evolution, examples from Triassic conglomerates/arenites in the Edvard Grieg field, Norwegian North Sea. Marine and Petroleum Geology, 93, 247-271.

MINISTRY OF MINES AND ENERGY (2019): Avanza la reactivación del sector de hidrocarburos: Suben reservas de petróleo en Colombia a 6,2 años. Continúa desafío en reservas de gas. URL: https://www.minenergia.gov.co/web/guest/historico-de-noticias?idNoticia=24107159

MONTEALEGRE, M., OCAMPO, N., SILVA, J., ROSERO, J., PARDO, A., BAYONA, G. & LAMUS, F. (2013): Chemostratigraphy and Characterization Diagenetic of Carbonate Rocks, Colombian NE (Cogollo Gr.). In 1st Latin American Geosciences Student Conference (LAGSC).

MOORE, C. (2013): Carbonate Reservoirs: Porosity and Diagenesis in a Sequence Stratigraphic Framework (Vol. 67). Newnes.

NATIONAL HYDROCARBON AGENCY (2019): Mapa de Áreas (Tierras). http://www.anh.gov.co/Asignacion-de-areas/Paginas/Mapa-de-tierras.aspx

SANDOVAL, M.E. (2000): Diagénesis de areniscas. CDCH UCV.

RAHMAN, M.J.J. & McCANN, T. (2012): Diagenetic history of the Surma group sandstones (Miocene) in the Surma Basin, Bangladesh. Journal of Asian Earth Sciences, 45, 65-78.

YU, X., LI, S. & LI, S. (2018): Clastic Hydrocarbon Reservoir Sedimentology. Springer.

YUAN, G., CAO, Y., ZHANG, Y. & GLUYAS, J. (2017): Diagenesis and reservoir quality of sandstones with ancient "deep" incursion of meteoric freshwater – an example in the Nanpu Sag, Bohai Bay Basin, East China. Marine and Petroleum Geology, 82, 444-464.

Petrophysical Evaluation of Sandstone Reservoir in Coal-Bearing Rocks in Rancheria Sub-Basin, Northeastern Colombia

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The petroleum system in Rancheria sub-basin shares similarities with the most important oil-producing basins in Colombia and Venezuela and, although unexplored, it provides ground to assume the possibility of a high potential to accumulate hydrocarbons (GARCIA et al., 2007; MESA & RENGIFO, 2011; SANCHEZ & MANN, 2015). On the other hand, the highest potential of coal-bed methane (CBM) in Colombia is in the Rancheria sub-basin (GARCIA, 2000; NICHOLSON, 2014), particularly in the Paleocene Cerrejon Formation composed of shales, sandstones and thick (50 m) coal beds (BAYONA et al., 2007; MORON et al., 2007; MESA & RENGIFO, 2011). Well logs are used to correlate zones of interest with hydrocarbon accumulation, to identify productive zones and to distinguish between gas, water and oil in a reservoir (ASQUITH & KRYGOWSKI, 2004; RIDER & KENNEDY, 2011; RICHARDSON, 2013). Petrophysical models applied in well logs interpretation linked with sedimentological descriptions transform direct measurement logs into rock-fluid properties such as shale volume, effective porosity, permeability and water saturation (ELLIS & SINGER, 2007; WU & GRANA, 2017). Once the petrophysical characterization of sandstones in these coal-bearing rocks was done, the potential to accumulate unconventional hydrocarbon deposits in Rancheria sub-basin could be established.

Gamma-ray, spontaneous potential, neutron, density and sonic logs, petrophysical properties laboratory data, and sedimentological core descriptions were used. The combination of gamma-ray and spontaneous potential logs was applied to calculate the shale volume. Neutron-density crossplot was used to identify lithological properties. The effective porosity was calculated using density and/or sonic logs. The water saturation was determined depending on the shale volume values: Archie´s equation (ARCHIE, 1942) with values less than 0.05, and Simandoux equation (SIMANDOUX, 1963) with values higher than 0.05. The Cerrejon Formation consists mainly of shales, coal beds and fine-grained

sandstones, and the average sandstones shale volume is about 25%. The porosity ratio of the Cerrejon Formation ranges between 8-18%; where the lower part of the formation holds intervals with less porosity (8%) than the upper part of the unit with values about 18%. The water saturation (Sw) value, calculated by the Simandoux equation, ranges between 10-25%. These results indicate the Cerrejon Formation bears positive values of petrophysical properties in the sandstones which are interbedded with shales and coal layers.

Keywords: *Rancheria sub-basin, Cerrejon Formation, petrophysical evaluation, well logs, effective porosity, water saturation, coal-bearing rocks*

References

ARCHIE, G.E. (1942): The electrical resistivity log as an aid in Determining some reservoir characteristics. Trans. Am. Inst. Mech. Eng., v. 146, 54-62 p.

ASQUITH, G. & KRYGOWSKI, D. (2004): Relationships of Well Log Interpretation in Basic Well Log Analysis Method in Exploration Series. American Association of Petroleum Geologists, (16), 140.

BAYONA, G., OCHOA, F.L., CARDONA, A., JARAMILLO, C., MONTES, C. & TCHEGLIAKOVA, N. (2007): Procesos orogénicos del Paleoceno para la cuenca de Ranchería (Guajira, Colombia) y áreas adyacentes definidos por análisis de procedencia. Geología Colombiana, 32, 21-46.

ELLIS, D.V. & SINGER, J.M. (2007): Well logging for earth scientists (Vol. 692). Dordrecht: Springer.

GARCIA, M. (2000): Evaluation of coal-bed methane potential of Columbia. In 2000 AAPG Annual Meeting.

GARCIA, M., MIER, R., ARIAS, A., CORTES, Y., MORENO, M., SALAZAR, O. & JIMENEZ, M. (2007): Prospectividad de la cuenca Cesar-Ranchería. Informe Agencia Nacional de Hidrocarburos, Colombia.

KENNEDY, M. (2015): Practical petrophysics (Vol. 62). Elsevier.

MESA, A. & RENGIFO, S. (2011): Petroleum Geology of Colombia–Cesar Rancheria Basin Vol 6. Agencia Nacional de Hidrocarburos-ANH.

MORÓN, S., MONTES, C., JARAMILLO, C., BAYONA, G. & SÁNCHEZ, C. (2007): Ciclicidad en la Formación Cerrejón. Boletín de Geología, *29*(1).

NICHOLSON, B. (2014): Establishing a Predictable Environment for Coal Bed Methane Development: The U.S. Experience. Norton Rose Fullbright meeting.

RICHARDSON, A.A. (2013): Well correlation and petrophysical analysis, a case study of "Rickie" Field Onshore Niger Delta. Int J Eng Sci, 2(12), 4-99.

RIDER, M.H. & KENNEDY, M. (2011): The geological interpretation of well logs. Rider-French Consulting Limited.

SANCHEZ, J. & MANN, P. (2015): Integrated Structural and Basinal Analysis of the Cesar–Rancheria Basin, Colombia: Implications for its Tectonic History and Petroleum Systems, 431-470.

SIMANDOUX, P. (1963): Dielectric measurements on porous media application to the measurement of water saturations: study of the behaviour of argillaceous formations: Revue de l'Institut Francais du Petrole 18, Supplementary Issue, 193-215.

WU, W. & GRANA, D. (2017): Integrated petrophysics and rock physics modeling for well log interpretation of elastic, electrical, and petrophysical properties. Journal of Applied Geophysics, 146, 54-66.

Petrogenetic Characteristics of Altered Basalts (Spilites) from Lasinja, Pokuplje

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The Lasinja quarry is located near the eponymous settlement, which belongs to community of Lasinja in the Pokuplje region, Croatia. Rocks from that area are members of the diabase-spilite-keratophyre association i.e. of the magmatic-sediment complex of Central Dinaride Ophiolite Belt (MAJER, 1978). The age of formation of the magmatic rocks in ophiolite suite, determinated on the basis of K/Ar and Rb/Sr methods, corresponds to 160 to 170 million of years (Middle Jurassic), but the emplacement of ophiolite suite took place in Upper Cretaceous (MAJER, 1993).

Nine samples of volcanic rocks characterised by pillow structure were taken from the Lasinja quarry. The petrographic analysis revealed that studied rocks are spilites having porphyritic, often glomeroporphyritic, ophitic to intersertal or ophitic texture. The main minerals are clinopyroxene and plagioclase, occurring in porphyritic rocks both as phenocrysts and as groundmass phases. The accessory mineral is ilmenite. The rocks are affected by hydrothermal alterations and weathering as evidenced by presence of different secondary minerals such as albite, chlorite, titanite, epidote, magnetite, calcite and leucoxene.

Clinopyroxene is usually fresh. Plagioclase, specially plagioclase phenocrysts show alterations into albite, epidote and chlorite, whereas ilmenite is partially replaced by titanite, magnetite and leucoxene. Chlorite is additionally the result of glass devitrification in porphyritic samples. Some rocks contain vesicles filled with secondary calcite and chlorite giving the rocks an amygdaloidal structure.

The major elements were determined by inductively coupled plasma atomic emission spectroscopy (ICP-ES) and trace elements by inductively coupled plasma mass spectrometry (ICP-MS). In diagrams for chemical classification of volcanic rock, studied samples plotted into basaltic or basaltic andesite field, using both, major and trace elements. The different discrimination diagrams based on main, immobile and incompatible trace elements indicated that studied rocks are products of subalkaline tholeiitic magmas and have the characteristics of magmas being recently extruded at a mid-oceanic ridges showing typical features of normal basalts of mid-oceanic ridges (N-MORB). However, the distribution of trace elements in a spider diagram and rare earth elements in a REE diagram give evidence that the studied rock deviate from the characteristics of typical N-MORB (Fig. 1) and could also be formed in back-arc basin. The similar results were found in analysed dolerites and diabases from other localities in the Central Ophiolite Dinaride Belt (LUGOVIĆ et al., 1991).

Keywords: *spilites, basalts, tholeiitic magmas, N-MORB, back-arc basin*

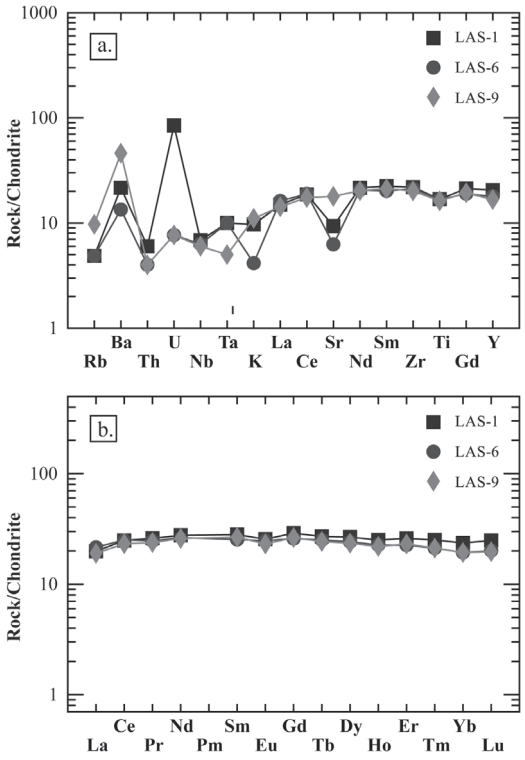

Figure 1. Geochemical characteristics of spilites from the Lasinja quarry: (a) Chondrite normalized (SUN, 1980) trace element patterns; (b) Chondrite normalized (SUN & McDONOUGH, 1989) REE patterns.

References

MAJER, V. (1978): Stijene »Dijabaz-spilit-keratofirske asocijacije« u području Abez-Lasinja u Pokuplju i Baniji (Hrvatska, Jugoslavija). Acta geologica IX/4 (Prirodoslovna istraživanja knjiga 42), 137-158.

MAJER, V. (1993): Ofiolitni kompleks Banije s Pokupljem u Hrvatskoj i Pastireva u Bosni. Acta geologica, 23/2, 1-46.

LUGOVIĆ, B., ALTHERR, R., RACZEK, I., HOFMANN, A.W. & MAJER, V. (1991): Geochemistry of peridotites and mafic igneous rocks from the Central Dinaric Ophiolite Belt, Yugoslavia. Contribution to Mineralogy and Petrology, 106, 201-216.

SUN, S.S. (1980): Lead isotopic study of young volcanic rocks from mid-ocean ridges, ocean islands and island arcs. Philosophical Transaction, Royal Society of London, A297, 409-445.

SUN, S.S. & McDONOUGH, W.F. (1989): Chemical and isotopic systematics of oceanic basalts: implications for mantle composition and processes. Magmatism in the ocean basins. Geological Society, Special Publication, 42, 313-345.

The Chronology of Quaternary Sediments Along the Eastern Adriatic Coast

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Pleistocene climate was marked by repeated glacial-interglacial cycles. During the last ice age much of northern Europe was glaciated as were the Mediterranean mountains (HUGHES et al., 2010); overlain by a thick ice cover which played an important role in glacial grinding and producing of voluminous fine grained clastic material. At the same time in the periglacial environment, south of the ice margin, large (braided-) river systems that carried large volumes of suspended and bedload material from the glacial meltwater and paraglacial processes, formed, as a consequence, vast floodplains exposed to strong wind activity. The North Adriatic Sea is a relatively shallow basin with depths up to 120 m and during the Late Pleistocene regression it was a wide alluvial plain. The relative sea-level dropped about 100-120 m and the shoreline was situated about 250 km south of its present-day position (SIKORA et al., 2014) resulting in terrestrial sedimentary environments in the North Adriatic basin and most of the recent coast and islands. Evidences of such environmental conditions can be recognized in sediment archives found along the Adriatic coast and on the islands.

To fully understand these evidences it is mandatory to establish a reliable chronological framework of the exposed sediments. The most appropriate methods available for dating of sediments are the optically stimulated and infrared luminescence dating methods (OSL and IRSL; respectively). In recent years numerous data were obtained from alluvial-eolian and eolian sediments from the Adriatic area. The results show that there was an intensive alluvial influence during the end of the Penultimate Glacial and the older parts of the Last Glacial period which is evidenced by coarser sediments, like breccia intercalations in eolian sand on the island of Hvar (WACHA et al., 2016; PAVELIĆ et al., 2011, 2014) or Lopud (KOVAČIĆ et al., 2018). During the Last Glacial period intensive wind activity and aridity as well as the sea-level drop of about 120 m below todays level, influenced the mass accumulation of dust which formed loess (e.g. WACHA et al., 2011, 2018; ZHANG et al., 2018). During the Last Glacial sand dunes were formed, too (e.g. Vis Island; WACHA et al., 2019; PAVELIĆ et al., 2014). Furthermore, Pleistocene coastal, marine and terrestrial sediments are also recorded at higher elevations, e.g. between 30 and 60 m a.s.l. on the island of Krk (MARJANAC et al., 1992) which could either be a climbing dune form or an evidence of active tectonics in the northern Adriatic area.

As part of an ongoing research, IRSL and OSL data will be presented with the purpose to unravel the stratigraphy and chronology of Quaternary sediments in the eastern Adriatic area and to reconstruct the dynamic and changing environment during the end of the Penultimate and Last Glacial periods.

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Keywords: *OSL and IRSL dating, Adriatic coast and islands, chronology, stratigraphy*

References

HUGHES, P.D., WOODWARD, J.C., van CALSTEREN, P.C., THOMAS, L.E. & ADAMSON, K.R. (2010): Pleistocene ice caps on the coastal mountains of the Adriatic Sea. Quaternary Science Reviews, 29, 27/28, 3690-3708.

KOVAČIĆ, M., PAVELIĆ, D., VLAHOVIĆ, I., MARKOVIĆ, F., WACHA, L., KAMPIĆ, Š., RONČEVIĆ, S. & DREMPETIĆ, D. (2018): Pleistocene alluvial and aeolian deposits with tephra on the island of Lopud (eastern mid-Adriatic, Croatia): Provenance, wind regime, and climate controls. Quaternary International, 494, 92-104.

MARJANAC, Lj., POJE, M. & MARJANAC, T. (1992/93): Pleistocene marine and terrestrial sediments with striata fauna on the island of Krk. Rad Hrv. akad. znan. umjet., Razred prir. znan., 463 (26), 49-62, Zagreb.

PAVELIĆ, D., KOVAČIĆ, M., VLAHOVIĆ, I. & WACHA, L. (2011): Pleistocene calcareous aeolian-alluvial deposition in a steep relief karstic coastal belt (island of Hvar, eastern Adriatic, Croatia). Sedimentary Geology, 239, 1-2, 64-79.

PAVELIĆ, D., KOVAČIĆ, M., VLAHOVIĆ, I., MANDIC, O., MARKOVIĆ, F. & WACHA, L. (2014): Topography controlling the wind regime on the karstic coast: late Pleistocene coastal calcareous sands of eastern mid-Adriatic, Croatia. Facies, 60/4, 843-863.

SIKORA, M., MIHANOVIĆ, H. & VILIBIĆ, I. (2014): Paleo-coastline of the Central Eastern Adriatic Sea, and Paleo-Channels of the Cetina and Neretva rivers during the last glacial maximum. Acta Adriatica, 55/1, 3-18.

WACHA, L., MIKULČIĆ PAVLAKOVIĆ, S., FRECHEN, M. & CRNJAKOVIĆ, M. (2011): The Loess Chronology of the Island of Susak, Croatia. Quaternary Science Journal – E&G, 60/1, 153-169.

References

WACHA, L., VLAHOVIĆ, I., TSUKAMOTO, S., KOVAČIĆ, M., HASAN, O. & PAVELIĆ, D. (2016): The chronostratigraphy of the latest Middle Pleistocene aeolian and alluvial activity on the Island of Hvar, eastern Adriatic, Croatia. Boreas, 45/1, 152-164.

WACHA, L., MONTANARI, A., LOMAX, J., FIEBIG, M., LÜTHGENS, C., KORBAR, T. & KOEBERL, C. (2019): Last Glacial Maximum giant sand dunes on the island of Vis, Croatia. In: KOEBERL, C. & BICE, D. (eds): 250 Million Years of Earth History in Central Italy: Celebrating 25 years of the Geological Observatory of Coldigioco, Geological Society of America Special Publication (accepted).

ZHANG, J., ROLF, C., WACHA, L., TSUKAMOTO, S., DURN, G. & FRECHEN, M. (2018): Luminescence dating and palaeomagnetic age constraint of a last glacial loess-palaeosol sequence from Istria, Croatia. Quaternary International, 494, 19-33.

Moissanite (SiC) in Sediments of Pazin Cave (Istrian Peninsula, Croatia)

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The Pazin cave was formed within the succession of the upper Cenomanian limestones (NW part of the former Adriatic Carbonate Platform – Milna Formation). The cave is passable to the southeastern part of the Martel Lake (sampling site) and represents a typical "Dinaric" fault zone (northwest-southeast, the average measured discontinuities 55/50). During the cave investigation a sediment sample of clayey silt was further investigated to get insight into the mineralogical composition.

A standard light and heavy mineral analysis was performed using sodium polytungstate (SPT; ϱ=2.8 g/cm^3) to separate the heavy and light mineral fractions. Analysis was performed by determination of 250-300 grains per sample using the ribbon counting method according to MANGE & MAURER (1992). In the light mineral fraction quartz grains predominate, while feldspar, especially plagioclase grains with typical polysynthetic lamellae, and chert grains are present in similar amounts. Mica is present in small quantities, as well. The sample contains 3.9 % of the heavy mineral fraction among which transparent heavy minerals predominate. Opaque minerals are also present. Among the heavy mineral fraction pyroxene grains prevail, mostly clinopyroxenes, with typical prismatic habitus and "hacksaw" cleavage. Some needle-like pyroxene grains are present, too. Pink garnets and some unknown blue glass-like fragments are also abundant in the sample. Rutile, tourmaline, staurolite, amphibole, epidote, and kyanite are present in a negligible amount. The uncommon blue grains detected in the sample show glassy to metallic lustre on thicker grains, conchoidal fracture and a high relief. The interference figure is excellent showing an uniaxial positive pattern. Since such mineral grains are very uncommon in cave sediments or any other sediment in the area, SEM-EDS analysis (JEOL Multi-Purpose scanning microscope (JSM-35) and INCAx-act Oxford Instruments detector) was applied to determine in more detailed the present mineral and to confirm the composition of the cave sediment.

SEM image revealed that the blue glass-like fragments show flat surface, without cracks. Nevertheless, some grains show traces probably of mechanical disturbances (scrap marks). EDS spectra showed only two elements; Si and C. Based on all optical mineralogical properties and confirmed by the EDS spectra it was concluded that it is very likely moissanite (SiC). Beside SiC, EDS spectra distinguished Ca, Mg and Fe peaks for some grains confirming the presence of clinopyroxenes (diopside-hedenbergite series?). Opaque minerals are mostly Fe-oxides and Fe,Mn-oxides (Fe-Mn nodules often found in cave sediments and Quaternary palaeosols and soils – unpublished data). Corundum (Fe-Al-oxides, Fe-Ti-oxides and Al-oxides) and barite were also detected in the investigated cave sediment.

Moissanite is very rarely found in sedimentary archives especially in Croatia. Synthetic SiC is produced at high-temperatures (up to 2500 °C) and under extremely reducing conditions and is often used as a replacement for diamonds due to its hardness. Furthermore, detected Al-, Fe,Al- and Fe,Ti-oxides in the sample are also most widely used as abrasives due to their hardness. The detected moissanite is probably synthetic and originated or resulted from industrial activity in the area. It is clear that the found grains in the cave sediment of Pazin cave are a result of pollution. Intensive contamination of the Pazin cave is an actual problem since the cave is located on a densely populated area, near the quarries and factories.

Keywords: *SiC, moissanite, cave sediment, Pazin cave, Croatia*

References

MANGE, M.A. & MAURER, H.F.W. (1992): Heavy Minerals in Colour. Chapman & Hall, London, p. 151.

LA-ICP-MS for U/Pb Geochronology: Which Analytical Capability is Right for my Laboratory?

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One of the most important dating techniques available in geoscience is the U & Pb system in zircons. The combination of laser ablation (LA) to inductively coupled plasma mass spectrometry (ICP-MS) has developed into the most commonly applied technique for in-situ, small scale, measurement of U/Pb ages.

A wide variety of ICP-MS are available, differentiated by mass analyzer and detection system. The choice of application typically governs which instrument is required. U/Pb geochronology by LA-ICP-MS is unusual, in that it is routinely analyzed on 3 different ICP-MS instruments.

Each ICP-MS has good reasons for being selected for U/Pb zircon analysis. The instruments available are: Quadrupole (Q)-ICP-MS (iCAP RQ/TQ), High Resolution (HR)-ICP-MS (Element XR) and Multi-Collector (MC)-ICP-MS (Neptune XT).

The purpose of the presentation is to explore and to illustrate the state of the art Isotope Ratio Mass Spectrometry available and their strengths for U/Pb zircon analysis.

Recent advances in instrumentation will be highlighted.

Keywords: *U/Pb dating, zircon, LA-ICP-MS*

The Obstacles in the Conservation and Management of Geoheritage

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The protection of geosites in Croatia started in the middle of the 20th century when in 1948 geosites Rupnica and Hušnjakovo were protected as first geological natural monument. Protection by law is the strongest mechanism for their conservation. Over the last 70 years, protection of new national geosites has been having its periods of ups and downs. The most fruitful period was between 1961 and 1975 when a large number of important geomorphological sites was protected (MINISTRY OF ENVIRONMENT AND ENERGY, 2019a).

In 2017, after a long eight-year procedure, the last geosite, Gorjanović loess profile in Vukovar, was protected as a geological monument of nature (MINISTRY OF ENVIRONMENT AND ENERGY, 2019a). What is more, expert assessment studies were made for several others geosites (Cave in the Tounj quarry and Tounjčica cave, Jama Vrtare male, Crnika and Pljuskara canyons). In addition to that, scientifically and educationally valuable remains of dinosaur fossils, which protection process started in 2007, after six changes of expert assessment study, to this day are not protected due to special requirements and legislative changes (CROATIAN AGENCY FOR ENVIRONMENT AND NATURE, 2018).

Frequent political and institutional changes in the nature protection sector is one of the reasons for the lack of protection. In Croatia, institutional changes began in 2003 with establishment of State Institute for Nature Protection as an expert institution. At the end of 2015, the Institute was merged with Environmental Protection Agency in Croatian Agency for Environment and Nature. The latest change occurred at the beginning of 2019 with abolition of Croatian Agency for Environment and Nature and its integration into Ministry of Environment and Energy.

The important role in the conservation and management of geoheritage have experts in the Ministry of Environment and Energy and public institutions that manage

protected areas at national, regional and local level. The organisational units of the Ministry dealing with protected areas employ three geologists/geographers. In the end of 2018 there were between 2 and 13 conservation experts working in 8 national and 11 nature parks, while 21 county and 6 local public institutions employed 6 of them at the most. Geologist and geographers comprised 16% of total 89 conservation experts in parks, while in county and local public institutions there were half as many geo-professionals, 8% of 73 conservation experts in total were geologists and geographers (MINISTRY OF ENVIRONMENT AND ENERGY, 2019b).

The effort for the management of geoheritage is possible to follow through activities which were carried out in the public institutions. In 2018, geological/geomorphological and speleological research and monitoring make 8% of total 742 activities in parks, whereas in county and local public institution they make only 1.4% of total 777 activities (MINISTRY OF ENVIRONMENT AND ENERGY, 2019c).

Another reason for the long protection procedures and inefficient management of geoheritage lies in the fact that nature protection is primarily based on biodiversity conservation. Therefore, human resources in the nature protection sector are concentrated on the experts in the field of biology and there is a lack of geological and geographical professionals in public institutions for management of protected areas, as well as in the Ministry. The same issue is with research and monitoring which are concentrated on biodiversity. Although geodiversity and geoheritage are neglected in the nature conservation, little progress is taking place in relation to the previous period before the establishment of State Institute for Nature Protection and public institutions for the management of protected areas.

Keywords: *geoheritage, geosites, conservation experts, nature protection*

References

CROATIAN AGENCY FOR ENVIRONMENT AND NATURE (2018): Database of expert assessment studies, Zagreb.

MINISTRY OF ENVIRONMENT AND ENERGY (2019a): Register of Protected Areas, Zagreb. Retrieved May 30, 2019 from http://www.bioportal.hr/gis/.

MINISTRY OF ENVIRONMENT AND ENERGY (2019b): Analysis of the annnual programs of protection, conservation, maintainance, promotion and use of protected areas for 2019, in progress, Zagreb.

MINISTRY OF ENVIRONMENT AND ENERGY (2019c): Analysis of the reports on implementation of the annnual programs of protection, conservation, maintainance, promotion and use of protected areas for 2018, in progress, Zagreb.

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