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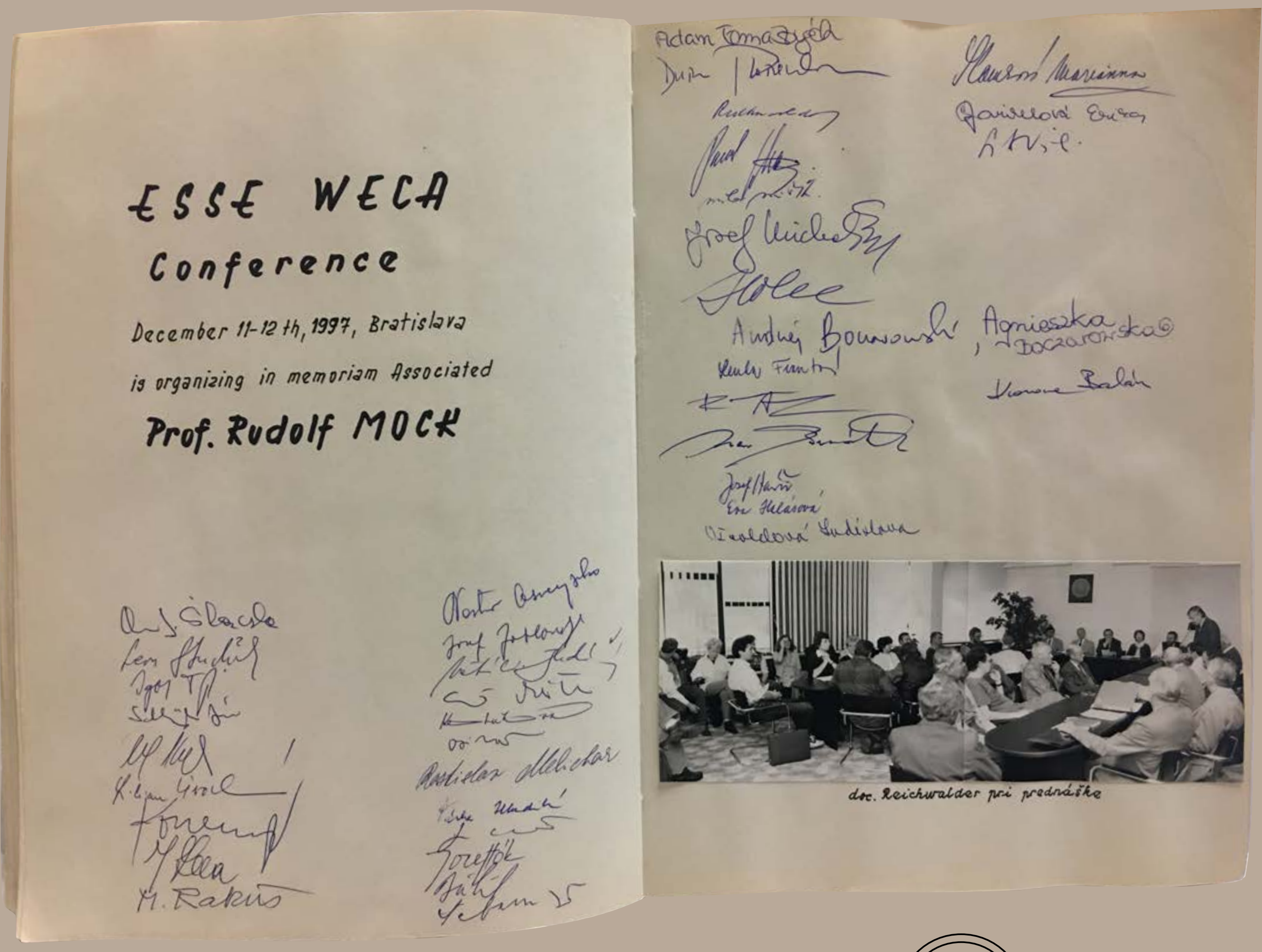
Bratislava, Slovakia

Environmental, Structural and Stratigraphical Evolution of the Western Carpathians

Natália Hudáčková – Ondrej Nemec – Andrej Ruman (Eds.)



COMENIUS UNIVERSITY BRATISLAVA

Abstract book

Faculty of Natural Sciences

prof. Mgr. Natália Hudáčková, PhD.
RNDr. Ondrej Nemec, PhD.
Mgr. Andrej Ruman, PhD.
Editors

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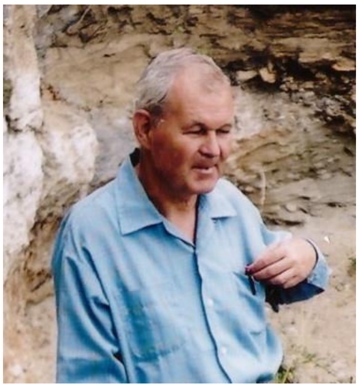
Prof. RNDr. Peter Holec, CSc.



Peter Holec worked for a long time as a scientist and teacher at the Department of Geology and Paleontology of the Faculty of Natural Sciences of the Comenius University in Bratislava, where he founded research school on extinct vertebrates from Slovakia. Later, at the Catholic University in Ružomberok, he taught the evolution of nature. He studied various fossil groups of vertebrates and with his erudition devoted mainly to the knowledge of the Miocene aquatic vertebrates. Besides the occurrence of "hipparions" and proboscideans within the Western Carpathian realm, he also contributed to discovery of whale fossils and the presence of early hominids of the Griphopithecus suessi species in the Miocene sediments of the Sandberg site. One of his most significant contributions is the co-authorship of newly described species of an early seal Devinophoca claytoni from the Bonanza site on Devínská Kobyla. He was a very popular teacher and throughout his career he educated several paleontologists who are still active today. At the Faculty of Natural Sciences of the Comenius University he was the guarantor of the Student Scientific Conference and participated at the founding of the Paleoclub in 2006. He received many awards, among them the Ján Slávik medal. We are happy that in 2024 we can dedicate the 13th edition of the ESSEWECA conference to the 80th anniversary of professor Peter Holec and thus celebrate his long successful career together with our dear colleague.

RNDr. Eva Halásová, PhD.

Eva Halásová worked at the Department of Geology and Paleontology at the Comenius University in Bratislava. By studying the calcareous nannofossils of the Mesozoic and Cenozoic, she contributed to Slovak paleontology mainly in the field of the Western Carpathians biostratigraphy. Deep insight and professional opinion classified her to become a member of the international team of specialists working on chronostratigraphy and neostratotypes of the Paratetethyan Neogene, as well as the international group at RCMNS and NCSEE. In the international Beriasian working group, appointed by the International Stratigraphic Commission for Cretaceous Stratigraphy she participated at the global correlation of the Jurassic-Cretaceous boundary. While working at the Department of Geology and Paleontology, she collaborated with geologists in prospecting for hydrocarbons, published numerous scientific articles, and was the supervisor of diploma and dissertation theses. We are happy that in 2024 we can dedicate the 13th edition of the ESSEWECA conference to the 70th anniversary of doctor Eva Halásová and thus celebrate his long successful career together with our dear colleague.

Prof. RNDr. Marián Putiš, DrSc.

The long-term head of the Department of Mineralogy and Petrology at Comenius University, teacher, projects leader and laureate of many awards, professor Marián Putiš is an expert in petrology of metamorphic rocks and regional geology. During his ongoing career he has been focused on unraveling the geodynamics of the Western Carpathian Variscan fundament. Driving force in his scientific direction within many Slovak and international projects plays the isotopic geochronology of the Western Carpathians, Eastern Alps (Austria), Dinarides (Croatia, Bosnia and Herzegovina), Egypt and Turkey. The footprint left in the field of his research´s interest is conspicuous and well-known, as evidenced by the outputs from databases with more than 2,500 citations to more than 190 published scientific works and by around 100 of scientific presentations at international conferences. Marián Putiš is a member of several professional geological societies, scientific and testing boards and commissions During his teaching career, he led 42 master's students and 8 PhD students. His remarkable contributions have been recognized through a series of prestigious awards, including the bronze and silver medals of Comenius University, the silver medal of the Dionýz Štúr State Geological Institute, the Ján Pettko award, and the Academician Bohuslav Cambel medal from the Institute of Earth Sciences of the Slovak Academy of Sciences for his outstanding achievements in geochemical and petrological research of igneous and metamorphic rocks. We are happy that in 2024 we can dedicate the 13th edition of the ESSEWECA conference to the 70th anniversary of professor Marián Putiš and thus celebrate his long successful career together with our dear colleague.

Integrated study of calcareous nannofossils and planktonic foraminifera across the Eocene/Oligocene transition in the Central-Carpathian Paleogene Basin (Western Carpathians)

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The study of Paleogene sediments of Upper Eocene to Lower Oligocene age was carried out at the localities of Bystré, Istebné and Ružomberok sections, based on calcareous nannofossils and foraminifera.

The sediments are part of the Central Carpathian Paleogene Basin and belong to the Huta formation, consists of up to hundreds of meters thick positions of variably calcareous claystones, claystones with siltstone lamination, or siltstones, and sections of flysch character.

Upper Eocene (Bartonian) calcareous nannofossils e was determined based on the first occurrence of the species *Reticulofenestra hillae* and *Reticulofenestra moorei*, which appear for the first time at the base of the NP 17 Nannoplankton Zone (sensu Martini 1971).

The Eocene/Oligocene boundary (Priabonian/Rupelian) interval was determined based on the biostratigrafical significant species *Isthmolithus recurvus* and *Reticulofenestra lockeri*. Other found species were characteristic for the nannoassemblage of the NP 21 Nannoplankton zone.

Calcareous nanofossils of the lower Oligocene age (Rupelian) were formed by a nannofossils with occurrence of the biostratigraphically important species *Helicosphaera bipuncta* and *Helicosphaera recta*. The youngest nannofossil assemblage, belonging to the NP 23 zone was found in the Ružomberok section, based on the first occurs of the species *Reticulofenestra ornata* and *Cyclicargolithus abisectus*.

Paleoecological conditions of the sedimentary area were characterised by the decline of Middle Eocene warm-water specimens of the genera *Discoaster* and *Sphenolithus* which were replaced by an increasing number of temperate water species such as *Coccolithus pelagus, Cyclicargolithus floridanus* and *Lanternithus minutus* and cold-water species from *Reticulofenestra* genus and *Isthmolithus recurvus*. Condition of the sedimentary area can be characterized as eutrophic and temperate water (Aubry 1992, Dunkley Jones et al. 2008, Fioroni et al. 2015). During the Eocene/Oligocene transition, an increase in the size of the *Reticulofenestra*, *Coccolithus* and *Chiasmolithus* specimens is visible. An increase in their central opening began to appear in the calcareous nannofossils assemblage. It is associated with global cooling, Antarctic glaciation, and atmospheric pCO^2 decline. The nutritional habits of species had to adapt to these changed conditions, which led to an increase in their body size (Ma et al. 2024).

In the Istebné borehole the Eocene sequence dominates by non-calcareous claystones with deep-water agglutinated microfauna like foraminifera *Reophax pilulifer, Rhabdammina cylindrica, Ammodiscus cretaceous, Glomospira charoides*, etc.. Hemipelagic interval contains a rich planktonic foraminifera assemblage, which belong to index species of late Eocene, like *Hantkenina alabamensis, Globigerinatheka index, Turborotalia cerroazulensis, Subotina linaperta, Catapsydrax unicavus,* etc. (cf. Coccioni 1988, Premoli Silva & Jenkins 1993, Pearson et al. 2008). Last occurrences of these species marked the Eocene/Oligocene boundary. Above the Eocene/Oligocene boundary, the sequence considerably changes by dwarfing of microfauna and appearance of new foraminiferal species. A high density of minute foraminifers implies an increase of productivity due to eutrophication, climatic cooling and/or upwelling. Majority of foraminifer assemblage became dominant by small-sized opportunistic species like *Globigerina* (*G. bulloides - officinalis* plexus), *Tenuitella* and *Chiloguembelina*, which are associated with species of *Dentoglobigerina* (*D. tapuriensis, D. venezuelana, D. galavisi*), *Paragloborotalia* and *Turborotalia* (*P. nana, T. ampliapertura*), *Globoturborotalita* (*G. ouachitaensis, G. martini*), and others. Lower Oligocene sequence reveals a pronounced change, Euxinic conditions resulted in poor planktonic microfauna of minute globigerinids, benthic agglutinated foraminifers still proliferated due to increase supply of organic carbon. The Lower Oligocene sequence grades upward to horizons of Menilite cherts, which imply a stepwise cooling, eutrophication and biosiliceous productivity.

Acknowledgement: The research was supported by projects VEGA 2/0012/24 and APVV 20-0079.

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The bond-topological maps and bond-topological field modelling in crystal chemistry of minerals

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In classical crystallography and crystal chemistry, the ionic model describes a crystal structure as a set of atoms (ions) in specific crystallographic sites that are physical objects – charged spheres connected through electrostatic interactions. This model was effective for inorganic compounds with simple structures but fell to difficulties in more complex structures. Moreover, classical ionic model interpretations have clear limits in predicting crystal structural properties, including factors that cannot be used in this interpretation. These include the internal structure of the atomic shell and electrostatic properties of bonds, Jahn-Teller distortion in *d* elements, short-range of neighbouring atoms, and long-range effects of the whole structure.

Bond-topological graphs allow for dealing with more complex crystal-chemical problems in structural fragments by calculating the bond properties. The bond-topological model is the specific structural fragment represented as a bond-topological graph with attached values of bond valences or lengths. The first step in bond-topological modelling requires defining a structural fragment, which will be developed as the bond-topological model. For the model to represent the complex structure, it should comprise all crystallographic sites and their bonds. The initial bond topological model can be developed when the topological graph is constructed. The graph edges have the values of bond valences attached.

Bond-topological models can be used to create a bond-topological map of real mineral structures. This map is a composite of bond-topological models added together having identical properties (bond lengths are the most easily obtainable) to the real structure. These models involved in the bond-topological map are derived from the starting model by substituting necessary ions following the substitution rules. The changes in bond-valence values can be relatively arbitrary but must follow a few specific rules: (1) the Bond-Valence Sum (BVS) rule – the sum of bond valences at each ion should be equal to the formal valence (FV) (this will be violated in the following steps) and cannot change if the FV did not change; (2) if FV of an ion at the specific site changed, stronger bonds obtain a larger increase and a smaller decrease in bond-valence than weaker bonds to satisfy electrostatic forces in the structure; (3) the change in the bond valence must be spread among all bonds of substituting ion – large differences in bond valences of one site produce large to even unbearable distortion of the site which results in unstable local structural arrangements.

The final unified bond topological map should accurately represent structural effects induced by coupled substitutions in the mineral structure. It can be tested by calculating bond lengths from the weighted sums of bond valences for every model. The weight of each model is the proportion of the end-member composition in the empirical formula of the studied mineral.

The bond-topological graphs can also be considered as a representation of the bond-topological field. The bond valences or lengths in the topological segments can be treated as discrete topological (bond-length, bond-valence) field values. The edges of the topological graph (bonds) are transformed into points of the discrete topological field. This field can then be represented as a bond-topological field diagram, i.e. bond-valence field diagrams visually illustrate the distribution of bond valences in the selected structural segment. Moreover, the subtraction of two bond-topological fields in the same structural segment (same bond-topological graph) results in the gradient bond-topological field, which shows changes between two compositional arrangements. In the bond-valence gradient field, the change is in the distribution of bond valences with the change in the charge of ions. In the case of bond lengths, the gradient illustrates the effects of their shortening or prolonging and, therefore, the compression, expansion, and distortion of structural polyhedra.

The bond-topological field modelling process requires the following steps:

1) Proposing possible substitutional mechanisms

2) Construction of initial models:

2a) Construction of bond-topological graphs for each substitution with ideal values

2b) Construction of discrete topological fields (bond-valence field and bond-length field and their gradients)

3) Testing of initial models – comparison of calculated bond lengths to empirical data

4) Refinement of models – correction of bond-valence values for each bond-topological graph according to empirical data

5) Testing of refined models

The bond-topological maps and fields not only allow us to study the structural and bond properties of minerals in detail. It could also allow for predicting the structural properties and stability of theoretical compositions, which were not yet observed in nature. It can also be a tool for studying the effects of substitutions that are not sufficiently examined because these effects are too weak for the standard analytical methods to observe.

Acknowledgement: This work was funded by the EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under the project No. 09I03-03-V04-00060.

Cenerian record in the Variscan Western Carpathian granitic rocks: geotectonic implications from zircon ages

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The record of inherited crust recycling during Variscan granitic magmatism in the Central Western Carpathians (CWC) was so far provided only by inherited zircon cores in various magmatic bodies. Preservation of entire (Cadomian) Cenerian zircon grains in Tournaisian peraluminous S-/I- type granites detected in western part of the Tatric Unit, namely in the Variscan segments Malé Karpaty, Suchý and Žiar massifs, confirm formation of Variscan granites from recycled mainly Cenerian sources (Broska et al. 2024 *in prep*.). Morphology and compositions of here observed Ediacaran / Cambrian zircons indicate felsic source and most probably S-type orthogneisses. They show ages ranging from 555 to 536 Ma what can connect them to Cenerian subduction accretion complex (SAC) in sense of the geodynamic and geomorphological model of Zurbriggen (2017). The new isotopic data from these granite bulk rocks (εNd) and from their zircons (εHf) show that recycled peraluminous Cenerian protolith is with large mafic contributions. Separated SAC into Galatian ribbon was later probably rotated before Variscan subduction and collision (see Neubauer et al. (2022) but the final Variscan granite flare up could be connected with slab breakoff formerly described for evolution of the Malá Fatra granite massif (Broska et al. 2022). In general, the formation of the Variscan granite arc could be related to the north-western collision of the Paleo-Adria on cratonized Cenerian SAC after subduction of the Balkan-Carpathian oceanic domain. The entire inherited zircons in the Variscan granitic rocks from the northern part of the Western Carpathians Tatric Unit were not identified (in the Malá Fatra Mts. and the Tatry Mts.) and these granites show a significantly higher input of lithospheric mantle and very intensive mixing forming even nonequilibrium accessory apatites. Thus, the granitic rocks from the Variscan Tatric segments on the basis of protolith with various intensity of mixed mantle can be divided into western and northern parts giving to granites specific geochemical features.

Acknowledgement: Support from Slovak Research and Development Agency: Grant APVV-22-0092.

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Brachiopods internal skeletal structures: testing the microCT method on Eocene and Miocene specimens from Croatia

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Croatian Natural History Museum (CNHM) houses abundant collections of Cenozoic (Eocene and Miocene) brachiopods from Croatia. Recently, we started the revision of the Middle Miocene (Langhian and lower Serravallian/Badenian) brachiopod collection from the Čučerje locality near Zagreb. Preliminary results showed a predominance of the order Terebratulida (Bošnjak et al. 2022) with more than 900 specimens. The classification criteria for these brachiopods include their internal shell structure, with the brachidium as an important element. Traditional methods for examining the interior of the shell involve destructive transverse serial sectioning (e.g., Cooper 1983 and references therein). However, X-ray tomography has also been conducted in more recent studies (e.g., Błażejowski et al. 2011, Gaspard 2013). In order to test the potential for gaining better insight into the taxonomy of fossil brachiopods from the CNHM, the inner shell structure was observed using a micro-computed tomography (microCT) device at the Natural History Museum of Vienna. For this analysis, we selected 13 terebratulid specimens of different ages and localities, including both Eocene and Middle Miocene specimens, along with one representative of the Rhynchonellidae. To compare the resolution of the shell interior based on the type of the sediment infill, we chose 6 Eocene terebratulids from the Island of Krk, Croatia, with a limestone infill, and the seven Middle Miocene terebratulids from Zagreb, with mostly sandstone infill. Preliminary results indicate that the Eocene terebratulids are not suitable for microCT analysis due to the similar mineral composition of the loop and the infill, and hence, invisible internal shell elements on CT images. Numerous Middle Miocene terebratulids have poorly preserved inner shell structures due to the fossilization processes, but some specimens retain recognizable parts of the brachidium providing the possibility to reconstruct these elements using 3D modeling. A similar result was observed in scans of the Middle Miocene rhynchonellid. Therefore, the preliminary results of this study demonstrate the microCT as a promising non-destructive tool for further taxonomic studies of the observed Middle Miocene brachiopods from the CNHM.

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The integrated biostratigraphy and palaeoenvironments across the Jurassic–Cretaceous boundary in the Dedina section (eastern Serbian Carpathians)

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The Jurassic–Cretaceous boundary remains the last system boundary without the GSSP and definition. Detailed study of Upper Tithonian to lower Berriasian pelagic carbonate sequence at Serbia focused on this problem. The Dedina section is characterized by wackestones and mudstones, intercalated with packstones, grainstones, and floatstones. It has rich ammonite record, not usual in pelagic carbonates of Alpine-Carpathian region.

All available fossil groups were investigated to get reliable stratigraphic subdivision of the Tithonian–Berriasian transition, including ammonites (Z.V.), calpionellids and calcareous dinoflagellates (D.R.), nannofossils (L.Š., A. S.), foraminifers (M.B.), and palynomorphs (P.S., M.S.) and enhanced by magnetostratigraphy (P.P., Š.K.).

Ammonite fauna with Crimean affinity comprises 10 genera with 17 species and 4 aptychi species. Based on the occurrence of *Pseudosubplanites grandis*, it belongs to the Grandis ammonite Subzone of the upper part of the lower Berriasian. Calpionellids allowed subdivision of the section to standard calpionellid zones including the Upper Tithonian Crassicollaria Zone (with Intermedia and Colomi subzones) and Berriasian Calpionella Zone (with lower Berriasian Alpina and Ferasini subzones and middle Berriasian Elliptica Subzone). The base of the Calpionella Zone is here tentatively used as a marker of the Berriasian base. Succession of calcareous dinoflagellate cysts allowed distinguishing the Proxima and Wanneri zones. Nannofossil *Nannoconus wintereri* proves the NC0 Zone. Foraminifer fauna contain zonal marker *Globospirillina neocomiana* and some other potential stratigraphic markers. Palynomorphs comprise long-ranging Lower-Cretaceous spores and pollen, and rare dinoflagellate cysts known from the Berriasian. Associations of microfossils, poor ichnofossil record, and standard microfacies SMF3, SMF4, and SMF5 points to oligotrophic open-marine conditions on the toe of slope to foreslope of the carbonate platform. Although the section is not appropriate due condensed sedimentation just at the Tithonian–Berriasian transition, several faults and remagnetization of some intervals, the results contribute to stratigraphic framework necessary to final definition and choice of the GSSP for the Berriasian.

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Determination of hydrocarbon zones by using advanced mud gas logging

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The hydrocarbon exploration and production were, and still represent a big strategic business in the world. The increasing ability to access large quantities of shale gas and tight oil, together with continuing discovery of new fields around the world, should ensure that we had enough natural gas for many decades to come, perhaps even several hundred years, and enough oil for the foreseeable future. After the beginning of the modern oil industry (from 1901), the exploration methods are constantly evolving. Except for the well-known geophysical methods, a less known geochemical analyse, so called Mud Logging was used commercially in 1939 for the first time during drilling.

The Mud Gas Logging (MGL) or Gas While Drilling (GWD) analyse is representing a detailed record of gas composition circulating in the drilling medium (mud) – ordinarily, when formation cuttings are drilled, they retain much of the formation pore fluid. This fluid is released to the mud column as the cuttings traveling up the annulus. When the drilling medium with cuttings flowing out from the well and finally reach the rig degasser and the shakers, the gas chromatograph measures the gas composition.

In general, the MGL is a statistical tool which uses the gas components (usually C_1-C_5; Pixler 1969) ratios for interpretation of hydrocarbon zones. As the standard and most used outputs are the triangular and pixler diagrams, e.g. TriPix plot. There are also many options for interpretation of advanced plots, which purpose is not only to maximize the obtained dataset during drilling, but also serve as a complementary tool. By combination of advanced MGL, drilling parameters (torque, weight on bit, stand pipe pressure, rate of penetration, mud flow out) and wireline logging data (Esteva et al., 2016) we can specify the "product" of the reservoir, e.g. gas wetness ratio (Wh), Balance ratio (Bh), Oil character ratio (Ch), gas quality ratio, gas density, oil gravity, fluid mobility/potential porosity, gas liquid ratio and porosity indicator (Crampin et al., 2013). By combination of Wh & Bh & Ch detailed information about the GOC (gas/oil contact), GWC (gas/water contact-in case gas field) and OWC (oil/water contact) are obtained (Haworth et al., 1985).

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Vegetation and climate oscilations during MCO/MCT in Central and Eastern Paratethys

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Originally, we analyzed the Late Burdigalian to Serravalian pollen spectra from the Czech and Slovak regions of the Central Paratethys, as well as the Mura-Zala basin and Transylvanian basin. These were compared with spectra from Eastern Paratethys in Turkey. The climax of the Miocene Climatic Optimum (MCO) revealed oscillations in climatic factors, such as increasing seasonality in temperatures and precipitation. Subsequent cooling and observable precipitation fluctuations were documented as evidence for the Miocene Climate Transition (MCT) (Doláková et al. 2021). The vegetation character in Central Paratethys underwent significant changes due to the Alpine uplift of the western Alps and Carpathians, initiating altitudinal zonality. Differences mainly in quantitative representation of zonal elements between northern localities (Czechia and Slovakia) and southern parts of this are (Slovenia, Romania) indicates increasing of latidudinal zonality. In Eastern Paratethys, palynospectra indicated an earlier trend of gradual cooling and a notable shift towards more arid and continental climate conditions. This trend may be linked to the presence of the vast moderate Eurasian continent (Vernyhorova et al. 2023).

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Fossils from the research of prof. RNDr. Peter Holec, CSc. documented in the paleontological collection of SNM – Natural History Museum.

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In the paleontological collection of the Slovak National Museum – Natural History Museum in Bratislava, there are registered about 300 specimens of vertebrate fossils, which were scientifically processed and published by prof. RNDr. Peter Holec, CSc. Most of the fossils come from field research in which the author participated, some fossils acquired from private collectors.

The range of Prof. P. Holec's research on fossil vertebrate remains is wide. He studies fossils of different groups of mammals (Proboscidea, Perissodactyla, Carnivora), fishes (Osteichthyes), chondrichthyans (Chondrichthyes) and reptiles (Reptilia). Some of the fossils he has scientifically analysed are documented in the paleovertebratological collection of the SNM – Natural History Museum. These fossils come from several localities – the Devínska Kobyla hill (Štokeravská vápenka quarry-Bonanza fissure, Sandberg, Waitov lom quarry), Včeláre 2, Mučín, Horné Strháre, Ladmovce, Moravský Svätý Ján, Okoč, Trojuholník cave in the Borinka Karst, and Trenčianske Bohuslavice.

From a scientific point of view, the most significant fossil is the skull of a Tertiary seal found in 1984 by Š. Meszároš in the Štokeravská vápenka quarry-Bonanza fissure, which was identified by P. Holec and I. A. Koretsky (2002) as a holotype of the new species of seal – Devinophoca claytoni. P. Holec was research leader for Slovak side of the Slovak-American paleontological field research at the site carried out in the 1990´s. The fossils obtained during the research are deposited in the SNM – Natural History Museum.

The museum paleontological collection contains also rare, unique fossils of Neogene terrestrial mammals and reptiles from the Devínska Kobyla - Sandberg site (Holec 1985, Holec & Schlögl 2000, Holec 2006, Schlögl & Holec 2004) and also rare finds of Neogene mammals (proboscideans, carnivores, primates, tapirs and reptiles) from the Včeláre 2 site (a limestone quarry south of the Včeláre village), where prof. P. Holec has done research at the end of the 1970´s. Most of the fossils from Včeláre 2 were scientifically analyzed and the results published (Holec 1985, Sabol et al. 2008).

The largest collection of fossils (approx. 170 specimens) from P. Holec's research (Holec, 2001) documented in the museum consists of the remains of Neogene marine vertebrates (Osteichthyes and Chondrichthyes) from localities on the Devínská Kobyla hill (Štokeravská vápenka quarry, Sandberg, Waitov lom quarry).

Prof. P. Holec processed a part of a large museum collection of shark´s teeth from the Mučín site (Neogene, Lower Miocene) (Holec et al. 1995), which the museum acquired from a private collector. He also processed shark teeth from the Horné Strháre site (Neogene, Middle Miocene) (Holec 2004), donated to the museum by himself.

From the Pleistocene fauna, P. Holec devoted his attention mainly to the finds of proboscideans – there are documented, for example, the finds of a teeth of a steppe mammoth (Holec 2014) and southern mammoth in the museum collection.

In the museum collection there is also paleontological osteological material from the archaeological research of dr. J. Bárta from the 1980´s in the Trenčianske Bohuslavice site, which P. Holec scientifically processed (Holec & Kernátsová 1997) and gave part of fossil remains of large mammals (about 70 specimens) to the SNM – Natural History Museum.

There are also other rare and isolated finds in the museum collection, which were the subjects of study of prof. P. Holec.

The collection of vertebrate fossil remains from the research of prof. P. Holec, stored in the collection of the SNM – Museum of Natural History, is of great scientific and documentary value.

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A Trans-Mid-European, Frasnian, mantle-sourced magmatic belt and its tectonic significance

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We discuss the tectonic significance of a ca. 375 Ma old magmatic zone that can be followed from the northern Massif Central (Limousin, Brevenne) over the southern tips of the Vosges and the Black Forest into the Helvetic basement under the Alps and further into the subcrop of the Carpathians (Finger & Riegler 2022). This zone includes basic and ultrabasic rocks of potential ophiolitic origin (Faure et al. 2009, Skrzypek et al. 2012, Winkler & Slaczka 1992) as well as mantle-derived granitoids with a subduction signature (Frasl & Finger 1988, Shaw et al. 1993, Zeh et al. 2024). All these rocks are interpreted to represent an extended Frasnian island-arc/back-arc-basin system that fringed the northern (north-western) margin of the Galatian terrane. They were then squeezed between Galatia and Armorica, when the two terranes collided in the Carboniferous to form a composite Variscan orogen.

Based on this interpretation, we suggest an essential modification to the Galatia-Armorica terrane model of Von Raumer et al. (2013): we propose that the Bohemian Massif, as well as most of the Vosges and the Black Forest (except their southernmost ends), is Armorican crust. We do, however, support the key idea of the Von Raumer et al. (2013) model that the Variscan orogen includes a northern Armorican terrane (or Armorican terrane assembly in the sense of Franke et al. 2017) and a southern Galatian ribbon terrane, which is prominently exposed in the Alpine/Carpathian basement. The Galatian terrane likely stems from East Gondwana and may originally have been positioned in the forefield of the Arabian-Nubian Shield (Finger and Riegler 2023). It, therefore, experienced a separate Early Palaeozoic development (Cenerian orogeny!) in comparison to the Armorica crust, which formed ahead of northern Africa.

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The Pannonian Basin revisited through geological, seismic tomographical data and numerical modelling

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In this contribution we intend to look to the Pannonian Basin through the recently compiled structural data, the recently obtained 3D shear wave velocity model, and the results of numerical modelling at different scales.

We carried out ambient noise phase velocity measurements, which were combined with existing phase velocity measurements from earthquake data (El Sharkawy et al. 2020). The obtained dispersion curves were converted to phase velocity maps, and then we calculated the real 3D shear wave velocity model. The velocity model depicts negative and positive velocity anomalies with respect to a background base model (Timkó et al. 2024).

As anticipated, the foredeeps all along the Carpathian chains show negative anomaly, and cross sections demonstrate that the European slab is subducted beneath the eastern segment of the orogen and the Pannonian Basin. One notable exception is the north-western segment of the Carpathians where a steeply dipping negative anomaly is present. This corresponds to region where the slab was detached, and where strike-slip tectonics accommodated the displacement transfer from the Alpine to the northern Carpathian thrust fronts; a process already envisaged by several former models. Part of the orogen, mostly the Western Carpathians, and the Pannonian Basin are marked by thinned crust and thin mantle lithosphere with negative anomaly; this is due to lithospheric thinning and asthenosphere upwelling. It is to note that mantle lithosphere could continue to be thinned after the crustal thinning stopped – during the “post-rift” phase – as suggested by the numerical models. The Western Carpathians, despite the presence of extensional crustal structures, show positive crustal anomaly, but the mantle shows negative anomaly integrating most of the Western Carpathians into the extensional basin system. In other part of the system, in the Transdanubian Range, the positive crustal anomaly corresponds to modest crustal faulting. However, the total crustal thinning is well-documented by the metamorphic evolution of and partial melting in lower crustal rocks sampled later in the Pliocene basalts as xenolites (Németh et al. 2021); extension could be accommodated by lower crustal flow.

Numerical models shed light into the temporal evolution of the entire system. Namely, the extensional deformation generally migrates from the basin margins towards the basin centre, but an early jump from the margin toward the opposite margin is also present in some experiments. This is in good agreement with the compilation of the ages of onset of basin subsidence and migration of activity of some major faults. This migration is driven by mantle flow, asthenospheric upwelling and subsequent thermal relaxation, all interacted with inherited weakness zone(s) – mostly former subduction zones – within the crust and mantle lithosphere. Consequences are contrasting subsidence and uplift patterns and a variable heat flow evolution in different sub-basins.

What numerical modelling does not show at the present status of research is the important contribution of the roll-back of the subducting European lithosphere. This process alone would induce formation of basins and their eastward migration within the Western and North-eastern Carpathians and contribute the scattered picture of basin subsidence pattern. While the decompressional melting in the lower crust and mantle resulted in the well-known magmatism is predicted by numerical models, the migration of volcanism from the centre toward the margin between 15.3 and 13.1 Ma (within the southern Alcapa domain, Lukács et al. 2024) is very probably due to subduction roll-back.

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Forensic optical and crystal-chemical investigation of changes induced by heat treatment in topaz from Ouro Preto and Caraí, Brazil

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Topaz, $Al_2SiO_4(F,OH)_2$, is one of the most favourable gemstones. Pure topaz is colourless but coloured varieties of topaz are known. Intensive blue topaz colour can be gained by ionic irradiation, followed by heating. The blue topaz with various colour intensity appeared at gemstone market under the trade names "Londonblue", "Swiss blue" and "Sky blue". Pink topaz is very rare and valuable, it is usually gained as a heat-treated from the orange protolith. Nowadays, new opportunities for gemstones' enhancement have been developed. Many retailers without the necessary education in the field offer a wide range of gemstones without a thorough knowledge of their origin deceiving the final consumer.

This forensic research was developed to provide general information to sellers and consumers alike. Its main purpose is to confirm or deny information about the gemstones provided by the retailer to protect consumers. We studied crystal-chemical and ge&mmological properties of coloured topaz from Brazil. The authenticity of light blue topaz from Caraí (CA) and imperial topaz from Ouro Preto (OP) with orange colour were investigated. We compared unheated and heated samples at various temperatures up to 1100°C based on their optical properties and chemical composition. We determined relationship between main and trace elements contents. Unheated and heated topaz samples were analysed by wide range of analytical methods to establish their authenticity by crystal-chemical and optical investigation.

When observing with the naked eye, CA sample had typical sky blue colour at room temperature, its colour decreased from sky blue to colourless already at 300°C and remained colourless up to 1100°C. The clarity was rapidly decreasing from 700°C to 1100°C with the growing cracks and fissures. The OP sample had its well-known orange colour, which is typical for untreated Ouro Preto topaz. This colour remained up to 500°C, at the temperature of 600°C, pink colour with orange tint appeared. The most attractive colour was obtained at 700°C, then its saturation rapidly decreased at 800°C, at 900°C we could observe pink colour with orange tint up to 1000°C. The temperature of 1100°C definitely turned OP sample to milky white colour. While untreated CA samples were very clean and transparent, OP samples were heavily included even to the naked eye, but the increasing temperature very positively affected the samples' clarity up to 700°C. From the 800°C to 1000°C, the cracks, fissures and clouds were increasing but clarity remained translucent. It turned to opaque at 1100°C.

The CA samples microscopic observation showed two phase fluid inclusions with orange iron compounds at 300°C, subsequently the fluid inclusions were dried and destroyed at 500°C, at 800°C to 1100°C. CA samples revealed fully dry inclusions with brown spots generating a cleavage at 1100°C. The OP samples heated at 300°C revealed brown-yellow limonite partially converted to hematite under the microscope. The fluid inclusions were observed at the 400°C, but at the temperature of 500°C and up to 700°C they were partially dried. Heating at the 700°C converted brown-yellow limonite to red-brown hematite. Fully dried inclusions appeared at 800°C. The opaque transparency of the OP sample at 1100°C made observation of the inclusions impossible.

Chemically, both sets of samples are very similar with differences only in F and OH anions and trace-element content. The CA samples are richer in F (>1.8 apfu) and very low in trace elements with Fe up to 125 ppm and Ge up to 153 ppm. The OP samples contain between 0.5 and 0.8 apfu OH and are more variable in trace elements – Cr up to 204 ppm, Ti up to 115 ppm but Fe and Ge are below 64 ppm.

Raman spectra were gained from the range of 100-1200 cm^{-1} and revealed the major bands for CA and OP topazes in the range of 235-290 cm^{-1} and 910-925 cm^{-1}. Minor bands are located at 150-170 cm^{-1}, 330-340 cm^{-1}, 400-410 cm^{-1}, 450-465 cm^{-1}, 518-525 cm^{-1}, 1150-1188 cm^{-1}. These bands were assigned: symmetric Si–O ring deformation (236-241 cm^{-1}); various vibrational modes of SiO_4 tetrahedra (at 265-271, 283-288, 836-844 and 910-916 cm^{-1}); stretching and bending modes of AlO_6 octahedra coupled with the bending modes of SiO_4 tetrahedra (at 401-408 and 454-465 cm^{-1}); stretching modes of Al–F (at 329-340 cm^{-1}); inplane bending OH-groups (at 1152-1163 cm^{-1}).

The optical absorption spectra of studied topazes were taken between 400 and 1000 nm. The CA samples spectra exhibit strong absorption at about 738 to 755 nm. Weaker absorption is observed at about 594 to 596 nm and 615, 634 and 664 nm. Maximum absorption is in the yellow, orange-red part of the visible spectrum giving rise to the CA samples' light blue colour and colourlessness because the most significant transmission is at about 500 nm in the blue region of the spectrum. On the other hand, the OP spectra showed most significant absorption in the range of 415-427 nm, 530-532 nm, 586-587 nm and 748-760 nm. The main transmission is at ca 700 nm in the red region and at the 450-500 nm in the violet and blue region of the spectra which enables OP samples to have orange or pink colour.

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Toad stone – the pre-scientific history of Scheenstia maximus (Wagner, 1863)

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A large number of fossils have been used medicinally and therapeutically from classical to modern times (ammonites, belemnites, sea urchins, amber, shark or fish teeth), (e.g. Duffin 2008). Among the fishes, the most important are the button teeth of the Mesozoic species *Scheenstia maximus*, which belongs to the group to which modern gars belong. *Scheenstia maximus* is known mainly from the Jurassic and Cretaceous of Europe: the Swabian Jura (Schwäbische Alb), the Franconian Jura (Fränkische Alb), the Anglo-Paris Basin, the Southern Alps and the Carpathian region. This contribution deals with some oldest evidence of the use of a *Scheenstia* tooth as part of the gem decoration on the early 13th-century reliquary of St. Maurus kept at Bečov nad Teplou Castle and on a 14th-century imperial crown kept in the treasury of Aachen Cathedral (Gregorová et al. 2020, Gregorová & Stehlíková 2024). Since the Middle Ages, these teeth have been considered to be toad stones found in the heads of toads. Toad stones were ascribed magical, protective and healing properties based on sympathetic medicine, the most important of which was the ability to detect and neutralise poison (e.g. Freller 1997). There are a relatively large number of written Latin references to these objects from this period. Colour differences in approximately 500 tooth specimens from over 24 European sites were examined to determine how tooth colour varied both within and among sites. The aim is to understand whether it is possible to determine the provenance of teeth set as part of the jewellery decoration in the reliquary of St. Maurus, in the crown on the bust of Charlemagne in Aachen and in other artefacts in the European territory. In addition, a comparison of the colours of toadstones from the main medieval sources with fossil *Scheenstia* teeth is discussed. We are preparing XRF analysis and Raman spectroscopy for future research.

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Composition of decapod assemblages from Upper Jurassic sponge megafacies of Kraków-Wieluń Upland (southern Poland)

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Upper Jurassic sponge megafacies, now extending from Portugal to the northern Caucasus, were formed in the deep-neritic environment along the northern margin of the Tethys Ocean. One of the well-known areas in Europe where these strata are exposed is Kraków-Wieluń Upland in southern Poland. Although decapod crustaceans from sponge megafacies of Poland have been known since the 19th century, our understanding of them improved significantly only in the last two decades, with studies focusing mostly on the taxonomy of Anomura (e.g., Fraaije et al. 2022, Krzemińska et al. 2015) and Brachyura (e.g., Klompmaker et al. 2020, Starzyk 2016), with a few studies discussing other groups (e.g., Garassino & Krobicki 2002).

A total of 356 decapod specimens, primarily composed of isolated dorsal carapaces (n = 172), were collected bed-by-bed from the middle Oxfordian to lower Kimmeridgian sponge megafacies of the Kraków-Wieluń Upland. The material comes from the localities of Bobrowniki, Lisowice, Młynka, Niegowonice, Ogrodzieniec, Wysoka, and Zawodzie with respective counts of 11, 78, 1, 32, 43, 5, and 2 specimens identified to the genus and/or species level. Specimens from Bobrowniki and Lisowice are early Kimmeridgian in age, originating from Bimammatum and Planula ammonite zones. Specimens from Zawodzie are late Oxfordian in age, originating from the Bifurcatus ammonite zone. Specimens from other localities are middle Oxfordian in age, including Plicatilis (Młynka, Wysoka) and Transversarium (Niegowonice, Ogrodzieniec) ammonite zones. Three species belong to three anomuran genera (*Ammopylocheles* sp., *Eopaguropsis blausteinensis*, and *Gastrodorus bzowiensis*) and 17 species belong to seven brachyuran genera (*Abyssophthalmus mirus*, *A. spinosus*, *Bucculentum bucculentum*, *Eodromites bernchrisdomiorum*, *Gabriella biburgensis*, *Goniodromites kubai*, *G. narinosus*, *G. serratus*, *Planoprosopon heydeni*, *P. rhathamingus*, *Tanidromites alexandrae*, *T. insignis*, *T. longinosa*, *T. nightwishorum*, *T. sculpta*, *T. scheffnerae*, and *T. schweitzerae*).

Due to the limited number of specimens, the localities of Młynka, Wysoka, and Zawodzie are not suitable for the identification of dominant species. The assemblage at Bobrowniki is dominated by *G. serratus* (27 %, n = 3); the assemblage at Lisowice is dominated by *G. bzowiensis* (32 %; n = 25) and *G. serratus* (19 %, n = 15); the assemblage at Ogrodzieniec is dominated by *G. serratus* (30 %, n = 13) and *G. bzowiensis* (23 %, n = 10). All the identified species at Niegowonice are represented by a maximum of two specimens.

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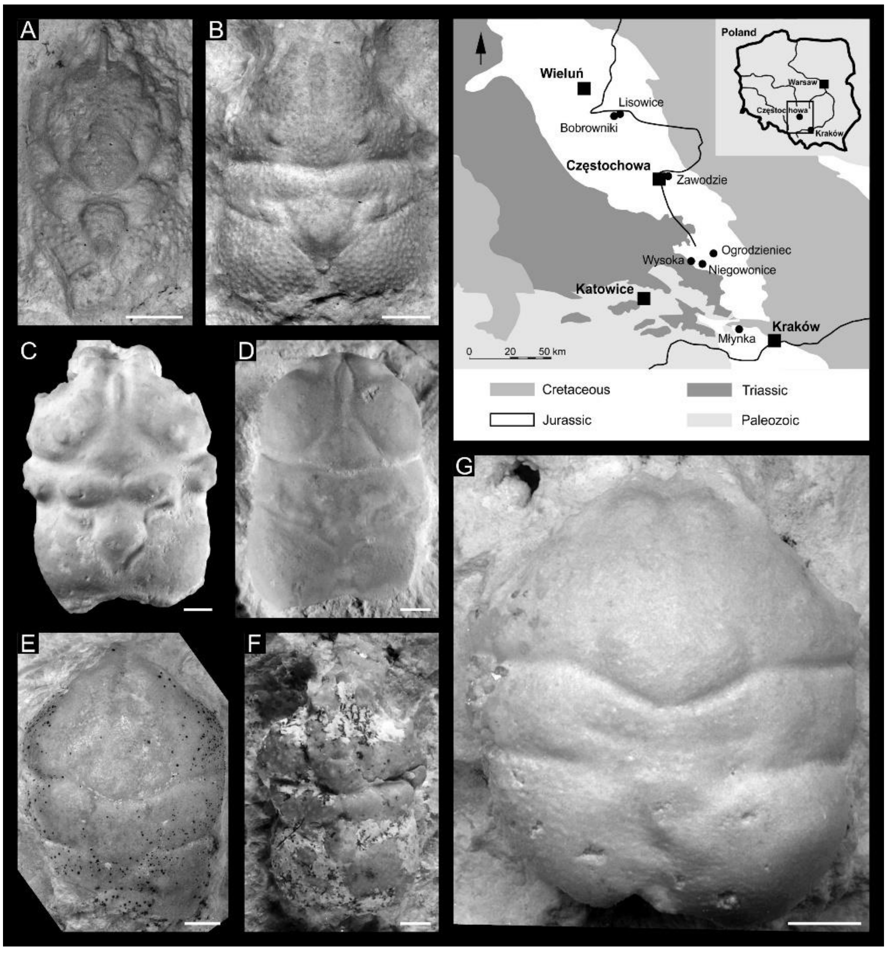

Figure 1: Map of the studied localities and some of the identified species; A: *Gastrodorus bzowiensis*, B: *Planoprosopon rhathamingus*, C: *Abyssophthalmus spinosus*, D: *Gabriella biburgensis*, E: *Tanidromites insignis*, F: *Bucculentum bucculentum*, G: *Goniodromites serratus*; specimens come from Lisowice (A – D, G), Ogrodzieniec (E), and Niegowonice (F); scale bars = 1 mm

First insight into a fossil small mammal assemblage from central Anatolia (Turkey)

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Material processed in this study comes from a large volume sample from the locality of Delice, Turkey, which was sampled during the VAMP (Vertical Anatolian Movement Project) project in 2010. Delice is located in central Anatolia in the southern part of the Çankırı-Çorum Basin, which is filled with Late Miocene to Pliocene sediments (Kaymacki 2000). A two-tonnes sample was taken for the purpose of studying small mammal fossil remains. The material was processed using the standard wet sieving method (Daams and Freudenthal, 1988). Delice locality yielded more than 150 small mammal teeth of rodents, insectivores and bats, belonging to the families Muridae, Cricetidae, Sciuridae, Eomyidae, Gliridae, Soricidae, and Talpidae. The small mammal assemblage from Delice is dominated by generalist murids (*Apodemus* sp. 1, *Apodemus* sp. 2, *Occitanomys* sp.), which make up about 62,5% of the assemblage. Approximately 19% of the assemblage is made up of taxa that preferred more wooded environments (*Keramidomys* sp., Pteromyinae indet., *Asoriculus* sp. and *Desmanella* sp.). Taxa indicating more open environment (*Allocricetus* sp., *Myomimus* sp.) make up 6,2 % of the assemblage. The remaining 12,4 % of the fauna consists of a semiaquatic desman – *Archaeodesmana* sp. (3,1%), an unidentifiable shrew – Soricidae gen. et sp. indet. (6,2 %) and a bat – Chiroptera gen. et sp. indet. (3,1%). Biostratigraphic analysis of the small mammal assemblage from Delice supports a preliminary correlation with MN 13 to MN 14 (Late Miocene to Pliocene) biozones based on the cooccurrence of the genera *Occitanomys* and *Allocricetus*. Based on our findings, the small mammal assemblage from Delice suggests a forested environment with local open areas.

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Structural evolution of the Tatric Unit between Pernek and Pezinská Baba (Malé Karpaty Mts.)

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The geological structure of the study area consists of the crystalline core of the Tatric unit and its surrounding sequences. In the studied area, the Tatric Unit is composed of the Pezinok and Pernek groups (metamorphosed rocks), the Bratislava and Modra massifs (granite rocks), and the Borinka and Kuchyňa cover sequences. The Tatric Unit rocks were affected by two main deformation phases, the older Variscan and the younger Alpine.

The Variscan deformation phases have been identified exclusively in the crystalline basement of the Tatric Unit. Locally, it was possible to observe isoclinal folded quartz veins as well as original probably sedimentary strata (S0) or older Variscan foliation (S^V_{-1}). However, three main deformation phases are recognized with certainty. The first and at the same time the most obvious deformation phase is the penetrative metamorphic foliation (S_1^V). The pervasive foliation (S_1^V) quite often contains, generally E–W oriented stretching and mineral lineations (L_1^V). Chronologically younger, Variscan deformation (D_2^V) is characterized by NE–SW shortening, with the formation of cleavages (S_2^V). Folds with axes oriented in the NW–SE direction (F_2^V) are often observed. In this deformation phase, stretching lineations (L_2^V) with NE–SW trend were identified in the shear zones. The last distinct Variscan deformation (D_3^V) is less intense and is characterized primarily by folds (F_3^V), which are mostly open to closed, symmetrical, rarely asymmetrical with probable tectonic transport top-to-the-SE.

The deformation structures of Alpine tectogenesis (foliations, lineations, fold planes and axes) were largely observed in the Jurassic – Lower Cretaceous sediments of the Borinka and Kuchyňa successions and to a lesser extent in the crystalline basement of the Tatric Unit. However, the manifestations of Alpine deformation are much less pronounced compared to penetrative Variscan deformation structures. Three main deformation phases were identified, while the primary S0 planar structure (bedding) was also clearly visible. In the first deformation phase (D_1^A), a relatively prominent planar structure (S_1^A) was identified, which accentuates the bedding (S0) due to pressure dissolution. The very well-developed stretching and mineral lineations of tectonic transport (L_1^A) related to the (S_1^A) foliation clearly point to the NW transport of overlying rocks. The cleavages with the direction of inclination to the SE and intersectional lineations arising in the rock as an intersection of bedding (S0) and tectonic foliation (S_1^A) together with fold axes (F_1^A) are directly related to them. Deformation (D_2^A) developed under conditions of pure shear and caused the flattening of carbonates probably during the Upper Cretaceous and Paleocene. A stylolitic foliation (S_2^A) related to pressure dissolution of rocks also began to develop in the marls and marbles. The youngest identified

Alpine deformation (D_3^A) is characterized by a compressional tectonic regime and the development of reverse fault shear zones with top-to-the-south kinematics.

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Teachers' attitudes towards the teaching of geological topics within natural science subjects

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During the solution of the project (051UK-4/2023) Modern textbook of geology for primary and secondary education of pupils in the sense of the new curriculum for the teaching of natural science subjects, we discovered that geological topics are taught cross-sectionally in the curricula of neighboring countries (Austria, Holland, Belgium, France) of the Science subject. Geological topics are consistently addressed in the 3rd cycle, the educational process, for pupils/students equivalent to the 9th grade of elementary school/quarters of 8-year high schools in education in France and in the subject of science of life on Earth in Belgium.

When preparing the study materials, we were inspired by the significantly inductive way of teaching geology in French schools (the equivalent is bilingual French education in eight-year grammar schools in Slovakia) and in the subject of Life on Earth (Belgium). In general, we have found that geological topics are much more prominently included in the teaching of physics and chemistry abroad, or that the physical principles necessary to explain geological phenomena and the study of the Earth's envelope and geohazards are thoroughly elaborated in geology textbooks.

As part of the above-mentioned project, we investigated the moods, attitudes and opinions of teachers regarding the teaching of geological topics within the natural science subjects. We asked the teachers through a questionnaire aimed at finding out their opinions and needs in connection with the creation of an ideologically new type of textbook on geological topics. The questionnaire contained 25 closed items. 146 teachers took part in the survey, of which 113 taught in schools in the Slovak Republic and 33 teachers came from the Czech Republic, while the research group consisted of teachers with experience from 0 to 42 years (the largest group consisted of teachers with a length of experience of 1 to 5 years). Primary school and gymnasium teachers participated in the survey most often. Based on the results of the questionnaire analysis, the majority of interviewed teachers believe that geology is an important part of education, whether in primary or secondary school. 43.8% of teachers fully agreed with the statement that it is an important part of education in primary school, 55.5% of teachers agreed with this statement in secondary school. The positive opinion (yes, rather yes) that geology is an important part of primary and secondary education was expressed unanimously by almost 90% of teachers. In the questionnaire, we further investigated what geology textbooks should look like, what support materials teachers prefer and which of the topics they need to support the most with textbooks. From the results, we learn that they envision support for teaching texts in the form of videos and animations for individual topics. Teachers consider the issue of the composition of the Earth and the atmosphere to be difficult and would welcome supporting materials prepared for it in the form of methodical materials and worksheets (workbooks) for students. 25.3% of teachers would need to process a topic related to the reshaping of the earth's surface and 19.9% photosynthesis with an emphasis on the connection with the formation of rocks, the importance of the catalytic activity of organisms, their use in waste management, but also with the connection to changes in the composition of the atmosphere over time, the origin of life and recording in rocks. The majority of teachers identified as a very necessary textbook for teachers thematically focused on the diversity of organisms, adaptation and evolution, fossils, mass extinctions of organisms and their protection and reshaping of the Earth's surface.

Geology is not a separate subject in Slovak curriculum documents, but is taught in primary schools cross-sectionally, mainly in the subjects of biology and geography. Since the curriculum reform of 2023 included the topics of geology in the educational area Man and Nature, we were interested in which subjects these topics should be made available to students. For topics related to the composition of the Earth and the atmosphere and the external and internal processes of the Earth, the majority of teachers marked the teaching subject geography, which is part of the educational field Man and Society. Regarding the topic Composition of the atmosphere, up to 34% of teachers believed that it should be part of chemistry lessons. The teachers quite clearly agreed that topics related to living organisms and evolution should be part of biology teaching. With topics focused on minerals and rocks, their formation, transformations, diversity and use, we can observe a greater variety of answers. About a fifth of teachers believe that these topics should be part of chemistry lessons.

Based on a detailed evaluation of the questionnaire, it follows that within the project it will be necessary to change the floating form of the "textbook", from loose notebooks for individual topics to a textbook for students and methodical materials for teachers, since most teachers probably want a traditional visual textbook for pupils and methodical material for students supplemented with online videos and supplementary materials.

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The Čertova pec Cave – A window into the world of Neanderthals

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The Čertova Pec Cave is situated near Radošina village in the Považský Inovec Mts. (48°33′N 17°54′E). Nowadays, this archaeological site is a 27 meters long tunnel-like cave with two entrances. However, at the time of the Neanderthals, the site had the character of a cave at least 35 meters long, with an entrance 4.5 m wide and 5.3 m high (Musil 1996).

The first excavations at the site were performed by L. Zotz in 1937 and later by F. Prošek in 1950 (Hokr 1951, Musil 1996), and probably carried out only in the Gravettian layer. During the last research of the cave in 1958–1961, headed by J. Bárta, three Palaeolithic layers with Gravettian, Szeletian, and Mousterian stone industry were found (Bárta 1972). The finding of a fireplace at a depth of 170 to 180cm (layer 4) with Szeletian (?) stone tools with surface retouch yielded an uncalibrated age of 38,320 ±2480 BP (GrN 2438) (Bárta 1965, Jöris et al. 2006). The AMS dating of animal bones (OxA-24106, OxA-24107, OxA-24108) at approximately the same depth in sectors close to the fireplace yielded datum range >45 to 40.1 kyr uncal BP (Kaminská 2014, Kaminská & Škrdla 2011). Another datum obtained from the ^{14}C dating of cave hyena remains indicates an age older than 50,000 uncal BP (Engelbrecht 2012).

Bárta (1972) described nine cave layers in his 1958–1961 excavations, and Musil (1996) dated these at Eemian (with *Ursus* cf. *taubachensis* and *Equus taubachensis*) through Last Glacial (with *Panthera spelaea*, *Crocuta crocuta spelaea*, *Ursus* ex gr. *spelaeus*, *Mammuthus primigenius*, *Coelodonta antiquitatis*, *Rangifer tarandus*) to Holocene. These layers were distinguished in a trench divided into 28 sectors (1–22, 25–27, IX–XII), with a maximum 2.7 meters depth. Based on Bárta's data and the osteological remains of 39 determined bird and mammal species, Musil (1996) reconstructed the cave's sedimentary history, animal occupation in the form of bear and hyena dens, and ancient human seasonal settlements from the Middle to Upper Palaeolithic. The combined geophysical survey (ERT, GPR) identified intact cave sediments, deposited under the debris filling and large limestone block, located at approximately 2m depth in the back part of the cave, close to its northeast (NE) entrance. These unconsolidated intact deposits represent the lower part of the Mousterian horizon (Putiška et al. 2016).

Since not all findings from the Bárta's research were analyzed by Musil, a complete revision research of the zooarchaeological material has now begun, also in connection with the planned new excavations at the site in 2025.

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Late Eocene decapod crustaceans from the Ďurkovec quarry (Western Carpathians, Slovakia): state of art after three decades of research

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The Ďurkovec quarry represents the stratotype locality of the Tomášovce Member (Borové Formation), a regional lithostratigraphic unit, composed of alternating fine-grained sandstones and siltstones and rare intercalations of carbonate arenites and conglomerates (Filo & Siráňová 1996). The age of the exposed strata in the quarry has been estimated as latest Priabonian (Gross 2008). The quarry is located 1 km south from the village of Spišské Tomášovce in the Spišská Ves district (GPS co-ordinates: N 48°57'0.21" E 20°28'21.74").

In the 19th century the Ďurkovec quarry was opened for sandstone extraction. The quarry has been studied since 1960s. Since 1988, staff from the Museum of Spiš in Spišská Nová Ves has performed palaeontological research there which yielded a fossil collection, including decapod crustaceans. Collecting efforts of present authors together with donations from private collectors helped to increase the number of collected decapod specimens up to nearly one hundred.

The first report of fossil decapods from the Ďurkovec quarry is that by Reuss (1859), who described *Ranina hazslinszkyi*, currently classified within the genus *Amphoranina*. Various aspects of fossil decapods from the Ďurkovec quarry were discussed in several studies (Hyžný 2007; Hyžný & Zágoršek 2012; Hyžný et al. 2018; Hyžný & Heteš in press.). The decapod assemblage is dominated by two brachuyran crab species, *A. hazslinskzyi* and *Coeloma vigil*, and accompanied by an axiidean shrimp *Ctenocheles* sp. and yet another brachyuran crab *Calappilia tridentata*. The latter two species has so far been documented from a single individual. The specimens often represent more-or-less intact individuals with preserved claws and walking legs, suggesting rapid burial and minimal to no post-portem transport. Moreover, specimens of *A. hazslinszkyi* are in some cases preserved perpendicularly to the bedding planes; they are interpreted as being covered by large amount of sediment while buried in the substrate, causing death of the animals. The presence of trace fossils *Thalassinoides* is indirectly linked with the burrowing shrimp *Ctenocheles* sp.

The fossil content of the strata exposed in the Ďurkovec quarry includes a tropical flora and marine macrofauna dominated by bivalves. Apart of decapod crustaceans, other faunal components include bryozoans, echinoids and shark teeth (Krempaská 1998, Holec et al. 2005; Hyžný & Zágoršek 2012). The entire assemblage inhabited shallow marine environment with the depth likely not exceeding 100 metres.

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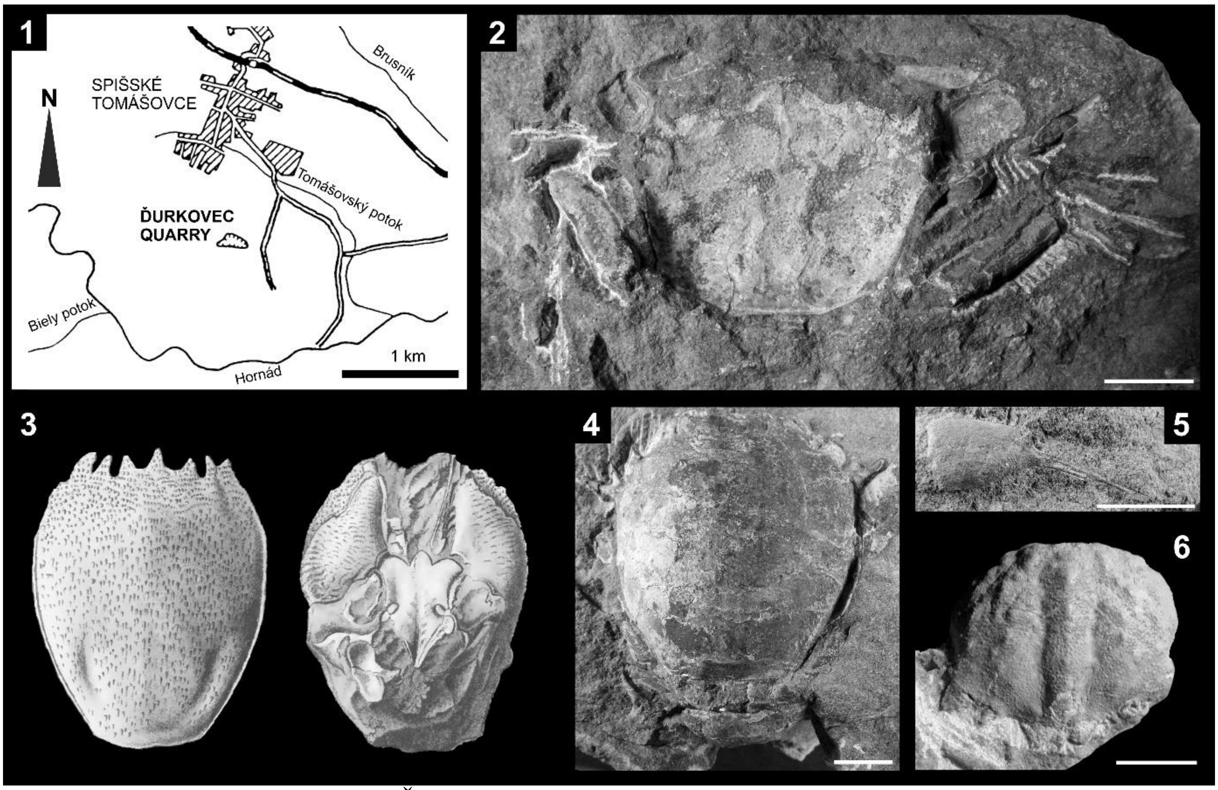

Figure 1: 1. Position of the Ďurkovec quarry. 2. *Coeloma vigil*, one of the dominant crab species. 3. *Ranina hazslinszkyi*, as figured by Reuss (1859). 4. *Amphoranina hazslinszkyi* preserved perpendicularly to the bedding planes. 5. Isolated claw of *Ctenocheles* sp. 6. isolated carapace of *Calappilia tridentata*. Scale bars represent 10 mm.

How many orogens formed the crystalline basement of the Western Carpathians? – Indications from lithology and petrochronology

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Since the times of Uhlig (1903) is generally known that the Western Carpathians crystalline basement (WCCB) was Variscan consolidated and amalgamated due to HT/MP(HP) metamorphism with partial anatexis and extensive granitic intrusions. The metamorphic rocks (volcano-sedimentary sequences) of the WCCB show flyschoid character, and their age was believed as Neoproterozoic to Lower Paleozoic what supported limited results of stratigraphy. Detrital zircon U–Th–Pb data from metamorphosed siliciclastics of the Tatric, Veporic and Gemeric units indicate an overall dominance of Neoproterozoic – mainly Ediacaran (ca. 600 Ma) zircons, with a minor role for Stenian–Tonian (ca. 1.2–0.9 Ga), Paleoproterozoic cratonic (ca. 2.2–1.8 Ga) and scarce Archean (ca. 2.6–3.4 Ga) zircons (Kohút et al. 2022; Soejono et al., 2024). Detrital zircons are interpreted to have been located at the Cadomian arc, derived mostly from the Saharan Metacraton and/or East African parts of northern Gondwana. Although, the maximal depositional age (MDA) of studied samples (ca. 566–458 Ma, Kohút et al. 2022; Soejono et al. 2024) indicate their sedimentation before the Late Ordovician, scarce magmatic ages from the gabbroic intercalations (ca. 383–371 Ma, Putiš et al. 2009) document the Late Devonian deposition in the upper parts of the volcano-sedimentary sequences. However, the older felsic peraluminous meta-igneous rocks (nowadays orthogneisses) provided magmatic ages (ca. 617–462 Ma, Putiš et al. 2009), while the older mafic meta-igneous rocks (today amphibolites/retrogressed eclogites) gave the crystallization age of a basaltic precursor at ca. 600–560 Ma (Gawęda et al. 2017) and ca. 503–480 Ma (Putiš et al. 2009; Burda et al. 2021). Noteworthy, important indications of the pre-Variscan evolution from the WCCB provided U–Th–Pb zircon spot dating by means of the SHRIMP that revealed a presence of the Cadomian restite zircon with the ages of ca. 555–536 Ma in the I-/S-types Variscan granites (Broska et al. 2024 in review).

An essential source of information about the pre-Mesozoic evolution of the WCCB are also the tonalitic gneisses, known from several amphibolitic complexes of the Western Carpathians, resembling the “*Altkristallin*” basement areas in the Alps. The best example of such “*Altkristallin*”, was identified in the Branisko Mts. (BM) of the Tatric Unit (Kohút 2024). The BM tonalitic gneisses have a “banded fabric” where the dark gneissic bands are composed of amphibole, plagioclase, biotite, and quartz. Their WR composition is metaluminous, magnesian and calc-alkaline (SiO_2 = 56–62 wt.%, A/CNK = 0.84–0.96, TiO_2 = 0.4–0.7 wt.%, CaO >5.0 wt.% and MgO >4.0 wt.%, low in Ba = 270–320 ppm and Sr = 170–280 ppm). The $^{87}Sr/^{86}Sr_{(t)}$ = 0.705–0.707; $\varepsilon Nd_{(t)}$ = +4.6~+3.6; $T_{(DM2)}$ =0.86–0.78 Ga; with low values of $\delta^{18}O_{(SMOW)}$ = 7.8‰; $\delta^{34}S_{(CDT)}$ = –0.11‰ and $\delta^{7}Li_{(L\text{-}SVEC)}$ = 0.52‰ indicate a lower crustal mantle influenced origin. The SHRIMP zircon U–Th–Pb data show a cluster of concordat spot ages between 500 and 400 Ma with concordia age of 474 ±13 Ma and 455 ±8 Ma, indicating proto-magmatic age. The first possible Cenerian metamorphism occurred before ca. 440–425 Ma, whereas the

Variscan metamorphic/magmatic reactivation took place at ca. 350–330 Ma. Zircon Hf isotopic data with $\varepsilon Hf_{(450)}$ = +8.1~+4.6 and two-stage Hf model ages $T_{(DM2)}$ = 0.98–0.79 Ga, along with $\varepsilon Hf_{(350)}$ = –0.9~–1.9 and $T_{(DM2)}$ = 1.26–1.20 Ga point to an increase of the crustal influence at their genesis.

Summarizing the above, the WCCB was formed by three major orogens such as Cadomian, Cenerian and Variscan. The dominance of Ediacaran detrital zircons indicates their origin at the Cadomian arc of northern Gondwana, from where the oldest (meta-)igneous rocks identified in the Western Carpathians come from. Rifting and thinning of the continental crust in the Cambrian–Ordovician times appears to be a major geodynamic feature for origin a complex association of mafic and felsic igneous rocks. The subduction–accretion complexes (SACs) became a part of the Cenerian subduction event. The WCCB evolution finished in Variscan subduction-collision orogeny by the HT/MP(HP) metamorphism with partial anatexis and widespread granitic intrusions activated by heat input due to slab breakoff (Broska et al., 2022).

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From Middle Jurassic extension to Late Jurassic obduction-related mélange formation: sedimentary records from the Adriatic passive margin in NE Hungary

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The two most interesting moments in the life-cycle of oceanic margins are the end of rifting and break-up, thus the first moment of becoming a passive margin, and the transformation into an active margin due to the closure of the ocean. This latter crucial event is the target of our investigation regarding the Adriatic passive margin facing the Neotethys Ocean during the Middle Triassic – Middle-(Late?) Jurassic interval. The reconstruction of this complex history is difficult at straight subduction zones and even more challenging at curved ones or at the termination/transfer zones of oceanic systems. This is the case with suture zones in the northernmost part of the Dinarides and its displaced segment, the Bükk nappe system. Up to now, there are two main competing models concerning the way of obduction and lower plate imbrication in the Dinarides – Albanides – Hellenides. One suggests, that the Western Vardar Ophiolite nappe juxtaposed the Adriatic margin during the Late Jurassic to earliest Cretaceous (Berriasian) with W- to NW-vergency, which predates the nappe-stacking of the Adriatic passive margin (Schmid et al. 2008, 2020; Djerić et al. 2012; Porkoláb et al. 2019). The other suggests synchronous ophiolite obduction and passive margin imbrication in the Bajocian – Bathonian interval, then propagation of the deformation both in the upper plate (internal thrusting within the ophiolite nappe), and in the lower plate during the late Bathonian – Oxfordian (Gawlick & Missoni 2019 and references therein).

Micropaleontological, sedimentological and structural investigation of more than thirty boreholes resulted in the detailed characterization and 3D depositional model of the Recsk Succession. The sedimentation in its Bajocian - early Callovian extensional half-grabens was characterized by pelagic limestones then dark shales with sandstone intercalations. Mass-flow deposits both from the footwalls of graben-bounding normal faults and from the Adriatic-Dinaric Carbonate Platform were frequent. The lack of contraction structures or ophiolite-derived material in the gravity mass flow exclude their attribution to any mélange units related directly or indirectly to the Neotethyan subduction front. In the overlying Tarna Olistostrome sedimentation lasted at least till the Tithonian, indicated by new nannofossil findings. This is the oldest possible age for the overthrusting of the ophiolite nappe over this segment of the

Adriatic passive margin. This suggests that the change from extension to shortening occurred between the Callovain and the Tithonian at the investigated northernmost termination of the Neotethys system.

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The geochemical character of synsedimentary volcanism in the Permian Haselgebirge Formation of the Eastern Alps (Austria): Implications for palaeogeographic models

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We investigated the geochemistry of ca. 50 synsedimentary volcanic rock samples collected in various regions of the ca. 250 Ma old salt-bearing Austroalpine Haselgebirge Formation. The volcanic relics occur mostly as loose dm-sized pieces associated with various Haselgebirge sediments. They are typically affected by strong low-T alteration, which caused significant changes to their major element composition, often involving gain of potassium and massive loss of sodium and calcium.

Based on the contents and ratios of immobile trace elements, the volcanism in the Haselgebirge can be classified as mainly basaltic. However, different mantle sources must have been at play. Synsedimentary volcanism in the eastern part of the Haselgebirge Formation (Lower Austria) was MORB-like and probably related to asthenospheric mantle upwelling. As opposed to this, the volcanic samples of the western Haselgebirge Formation (Hallstatt and Lammertal, S of Salzburg) display predominantly alkali-basaltic trace element characteristics. It is hypothesized that they represent magmas from a metasomatized lithospheric mantle. Finally, a third basalt type with remarkably low Nb and Ta contents could be identified in the Grundlsee region (location Wienern). It represents a local subduction-modified mantle source or a local assimilation of crustal material.

Our research highlights a significant change of the type of magmatic activity in the Austroalpine Unit during the Permian. While according to literature data, magmatism in the early and middle Permian was dominantly felsic (granitic), a significant switch to mafic magmatism occurred by the end of the Permian. This likely mirrors the beginning break-up of the local Pangea crust and the rise of a upwelling mantle antedating the Triassic opening of the Meliata Ocean. The observed source variations within the Haselgebirge basaltic volcanism point to a comparably greater degree of lithosphere thinning and upwelling of asthenosphere in the east. This accords with geological models where the (Triassic) Meliata Ocean gained its greatest width in the Carpathian realm while wedging out towards the western Eastern Alps.

Holocene environmental changes revealed by subfossil Chironomidae and biomarkers from an alpine lake in the High Tatra Mountains (Western Carpathians)

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A paleolimnological investigation of Popradské pleso (1,494 m a.s.l., High Tatra Mts.), a lake of glacial origin, was conducted to determine the timing of deglaciation and the influence of Holocene climatic oscillations. The uppermost 250 cm of a 638 cm sediment core, spanning the last ~10,100 years, was analysed for subfossil chironomids, biomarkers, total organic carbon, and total nitrogen. The oldest studied deposits date back to the Early Holocene and consist of fine laminated mud. The chironomid assemblages were species-poor and dominated by *Micropsectra radialis*-type and *Pseudodiamesa nivosa*-type, which indicate very cold, ultra-oligotrophic and oxygen-rich lake conditions. Biomarker results revealed a tundra environment in the lake catchment, typified by the presence of lithophythic lichen and *Sphagnum* moss, without higher vegetation. These conditions likely resulted from the continued presence of a glacier in the upper Zlomisková dolina valley, from which the Ľadový potok stream feeds lake Popradské pleso. The transition from a glacially influenced lake system occurred at ~9,900 cal years BP, and lasted until ~9,700 cal years BP, with sediments consisting of homogenous mud. The progression towards a warmer and more productive system is evident from the decreasing abundances of previously dominant chironomid taxa and the increasing proportions of *Tanytarsus lugens*-type. At the same time, the abundance of diploptene, a biomarker indicative of soil cover development, increased, followed by rising levels of coniferous vegetation biomarkers. After the transition, the organic-rich gyttja deposits recorded an overall increase in chironomid taxonomic richness, with the community dominated by the more thermally plastic *Tanytarsus lugens*-type, *Psectrocladius psilopterus*-type and *Heterotrissocladius marcidus*-type. Until mid-Late Holocene, the composition of chironomid assemblages remained relatively stable and was characterised by high proportions of rheophilic taxa, which along with the high abundance of *Sphagnum* biomarkers, indicate higher precipitation levels. Starting around 2,800 cal years BP, and until the present, a decline of both rheophilic chironomid taxa and *Sphagnum* moss suggests a shift towards a drier climate. Finally, the lower productivity and colder temperatures of the Little Ice Age were reflected in the chironomid record by an increased abundance of *Heterotrissocladius marcidus*-type, identified in the youngest analysed deposits.

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The interaction of man and the environment in the context of prehistoric cave settlements in Slovakia - multidisciplinary research

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Cave sediments in karst areas represent an important archive for understanding past climates and environments. No other landscape type encapsulates such a wide range of palaeoecological and palaeoclimatic data in a small area. The caves form niches naturally protected from adverse weather conditions, which is why man used them as a refuge. They were often inhabited repeatedly, therefore they contain valuable archaeological - cultural and chronological information. They represent an ideal place for research into the relationship between man and the natural environment.

Within the INTERCAVE project we focus on the revision research of caves that have been repeatedly (and almost completely) explored: Čertova pec (Musil 1996, Kaminská et al. 2011); Deravá skala (Kaminská et al. 2005), partially explored: Hučivá diera (Valde-Nowak et al. 2022), Veľká ružínska Cave (Nemergut et al. 2023), as well as on an unexplored cave: Očko near Ružín (Nemergut & Soják 2022). Each of these caves has its own specific features and significance due to its geographical location, age and the time when it was inhabited. The project aims for multi- and interdisciplinary processing, including the evaluation of proxy data obtained, with the intention of validating existing hypotheses regarding the evolution of climate and environment and their impact on prehistoric societies in the regions under study. There are similarities and differences among the studied caves and their settlements. As part of the research, we find out whether these variations are caused by the location, geographical features, the morphology of the caves and their surroundings, or by the fact that they were explored in different periods by different researchers using different research methodologies. After answering these questions, we want to focus on the reconstruction of settlement activities. We will then try to define/reconstruct aspects of the relationship/influence of the natural environment on the identified activities of prehistoric populations.

This research is multidisciplinary and internationally conceived and includes various methodological approaches:

- Archaeology - raw material, technological and typological analysis of lithic industry;

- Geodesy - spatial evaluation of the finds situation and finds in GIS space;

- Geology, pedology - micromorphology, granulometry, whole-rock and clay analysis of sediments using Rtg. powder diffraction, magnetic susceptibility, presence of phosphorus, stable isotope (O and C) analysis of penumite and alluvial sinters, their dating (C14, U/Th) with verification of possible occurrence of sintered soot, observation of microtextures and chemistry of speleothems (penitec and sinters) on electron microprobe and SEM, OSL dating;

- Archaeobotany/Palaeobotany - taxonomic and quantification analysis of charcoal, seeds, rhizomes, pollen grains (in order to reconstruct the vegetation around the cave and the economic activities of the human populations inhabiting the cave), C14 dating;

- Palaeontology - taxonomic, taphonomic and palaeoecological analysis of vertebrate osteological material and malacofauna remains; isotopic analysis of biominerals (15N, 13C, 18O, 87/86Sr), microstructural analyses of dental cementum on mammalian teeth (to determine the annual season of death and age of the animal, the age structure of the population and the seasonality of the studied sites) and C14 dating. In 2024, the Deravá skala cave was re-examined using modern research methods. It represents an important locality with evidence of the transition between the Middle and Early Palaeolithic (approximately 50,000 – 40, 000 years ago). This is the period when the last Neanderthals die out and are replaced by anatomically modern people. This is a key period of human evolution that was relatively short (from a few hundred years to potentially several thousand years). The following scientific institutions participate in the research: Australian Museum Research Institute, Australian National University, University of Sydney, University of Melbourne, University of Paris, University of Vienna, Cambridge University, Max Planck Institute, Griffith University, Institute of Archaeology - Slovak Academy of Sciences, State Geological Institute of Dionýz Štúr, Department of Archaeology - Constantine the Philosopher University Nitra, Institute of Geology of the Czech Academy of Sciences, Faculty of Natural Sciences - Comenius University Bratislava, Slovak Museum of Nature Protection and Speleology.

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Mid Permian to Late Triassic felsic and mafic magmatism in the Austroalpine basement and cover: Review, new data and tectonic setting

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The aim of this contribution is to review the distribution of the widespread Mid Permian to early Late Triassic felsic and mafic magmatism in the Austroalpine basement and post-Variscan cover, to present hitherto unpublished data, propose the location of the magmatism in the basement and cover in relation to the Austroalpine nappe stack, which formed in the Cretaceous. Older data on Mid Permian to early Late Triassic bimodal magmatism were recently compiled in Neubauer et al. (2022). Since then, many data on felsic and mafic magmatism of this period were published (Chang et al. 2022, 2023; Huang et al. 2022; Reiser et al. 2024) and even more data are in preparation for publication. These include metagabbros associated with the Lower Austroalpine (LAA) Grobgneiss batholith providing evidence for two stages of plutonism, at ~265 Ma (Middle Permian), almost contemporary with the Middle Permian Grobgneiss, and at ~251/252 Ma (Permian-Triassic boundary). The gabbros derive from partial melting of complex sources involving asthenospheric mantle (Group I) and lithospheric mantle modified by subducted slab and crustal contamination (Group II), both include the two age groups.

Felsic plutonic rocks were studied in three distinct tectonic units in Centralalpine (CA) unit (Gleinalpe to Rappolt complexes belonging to different CA nappes; Fig. 1). These show ages between 264 to 272 Ma and could be tentatively explained, together with LAA Grobgneiss, to represent one single plutonic plumbing system, although these units where highly differently affected by the Cretaceous, in part high-pressure, metamorphism (Fig. 1).

The Wolfsberg Orthogneiss underlying the Koriden Complex gave weighted mean $^{206}Pb/^{238}U$ zircon ages of 256.8 ± 5.6 Ma and 258.0 ± 3.4 Ma. Samples of the Rosskogel Porpyhroid and Lower Austroalpine cover ages of 264.7 ± 5.8 Ma and 269.0 ± 1.3 Ma similar ages as those of Reiser et al. (2024) incl. tuffaceous metaclastics from the latter succession with ages as young as 256.7 ± 1.4 Ma.

A detailed view on the distribution of the early Late Triassic bimodal magmatism reveals that nearly all Austroalpine cover units are free of felsic and mafic volcanics except the LAA ones (Radstadt, Rosskogel, and Wechsel) as well as Northern Calcareous Alps (NCA) and except mafic magmatic rocks in the evaporitic Permian/Triassic mélange mainly within the Lower Juvavic unit. In pre-Pemian basement units, plutonic rocks occur in the Schladming (Huang et al. 2022), CA units (Fig. 1), Raabalpen and Eisenkappel (Miller et al. 2011) complexes. The lack of volcanics in cover units makes it difficult to put basement rich in magmatic rocks underneath the cover making present reconstructions unlikely. Taking all information together, the pre-Permian reconstruction suggests two major sites in the basement locating the bimodal magmatism and partly associated HT metamorphism in the Permian: (1) the distally located LAA Raabalpen-Radstadt realm as main place of extension, and (2) more proximally located Upper Juvavic realm, which later represented the extended future passive margin of the Meliata realm. Consequently, a new tectonic reconstruction is proposed, which could be extended to Western Carpathians.

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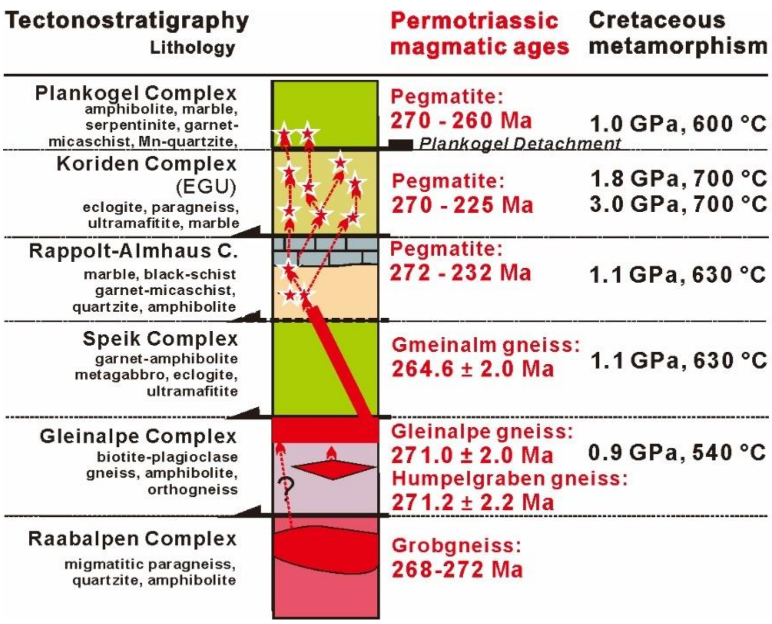

Figure 1: Tentative model for the felsic plumbing system with U-Pb zircon magmatic ages in LAA and nappes (from Neubauer, in prep.). For explanation, see text.

Reconstruction of Paleostress Conditions in the Malužiná Fm. of the Malé Kapaty Mts.

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The thin-skinned Hronic nappe system represents the structurally highest tectonic unit in the Late Cretaceous thrust stack of the Central Western Carpathians. Structurally, the Hronic Unit is a complex nappe system with numerous smaller nappes (Kováč & Plašienka 2003). It primarily consists of a Permian volcano-sedimentary sequence and Triassic carbonate sediments, which are exposed in various regions of the Central Western Carpathians. The basal part of the Hronic nappe system is represented by the uppermost Carboniferous-Permian volcano-sedimentary sequence known as the Ipoltica Group. This group includes the uppermost Carboniferous to lowermost Permian Nižná Boca Formation and the Permian Malužiná Formation (Vozárová & Vozár 1988).

The Nižná Boca Formation consists of a regressive lacustrine-deltaic succession, including sandy shales, sandstones, and conglomerates. Overlying this is the Malužiná Formation, which is characterized by three upward-coarsening sedimentary megacycles. These cycles consist of fluvial-lacustrine and alluvial red beds, with local evaporates (Olšavský & Ferenc 2002). The Malužiná Formation is notable for the presence of large basic to intermediate volcanic rocks, with a continental tholeiitic magmatic signature. These volcanic rocks are associated with a regional extensional tectonic regime, which facilitated the development of a rift structure. Extensive andesitic to basaltic volcanism occurred during two major eruption phases: the older phase corresponds to the first megacycle, while the younger, more voluminous phase is associated with the third megacycle (Vozár et al. 2015).

Triassic sediments directly overlie the Ipoltica Group and form a comparatively thick succession. These sediments are primarily siliciclastic, including quartzitic sandstones, followed by variegated shales and a wide range of carbonates, reflecting various parts of a shelf environment, from reef platforms to pelagic intra-shelf basins. Jurassic and Lower Cretaceous limestones are relatively rare (Vozárová & Vozár 1988).

This study is concentrated on the paleostress analysis of two localities in the Malé Karpaty Mts. The deformation structures were measured and recorded in the Permian volcano-sedimentary sequence of the Malužiná Formation.

Based on kinematic analyses of meso-scale faults (slickensides), several brittle deformation stages characterized by certain properties of the reconstructed stress field have been discerned. We have employed the program Win_Tensor for the computation of stresses and the separation of the faults into homogenous groups. Relative superposition of individual paleostress states was derived from field structural relationships. An observed chronology of deformation phases can be divided into the five different palaeostress fields. The kinematic analysis of fault-slip data confirmed predominant strike-slip nature of the fault during the whole history.

The first deformation stage was accompanied by formation of the NW–SE trending sinistral and NE–SW trending dextral strike-slip faults. The oldest deformation phase is characterized by compression in the W–E direction that was generated during the strike-slip tectonic regime. The second deformation stage is characterized by the NW–SE to WNW–ESE oriented σ^1 and resulted in a transpressional to compressional tectonic regime. It resulted in formation of the conjugate strike-slip faults, including the W–E oriented dextral strike-slip faults that predominate over the sinistral faults. For this event, the formation of a small number of NE–SW striking reverse faults is typical. Transpression continued during the third deformation phase that resulted from shifting of the principal compression axis toward the N-S to NE-SW orientation. For this event, the formation of a great number of NE - SW dextral strike-slip faults are typical. The fourth deformation phase was resulted from shifting of the principal compression axis toward the NNE-SSW to NE-SW orientation. The dextral strike-slip faults oriented NNW-SSE prevail over the ENE-WSW sinistral strike-slip faults. At the same time, the great number of oblique-slip reverse faults striking in the NW-SE direction were formed, generated in a pure compressive regime. The latest deformation stage is characterized by the onset of a general extensional tectonic regime, dominated by an extensional component of the stress field oriented in the NW–SE direction. The existence of large number of normal faults oriented in the NE-SW direction is likely caused by the relaxation of compressive stresses in the area.

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Benefits of ffective geological heritage interpretation in geotourism on popularizing Earth sciences and enhancing knowledge in general public

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The geosphere, with its geological heritage, represents the basis of all ecosystems, including those in which humans live. It affects where we build our homes, our quality of life, and our very safety. In addition, we are currently facing the challenges of sustainability and the use of raw materials, which are often an unknown concept to the general public, even though they are an essential part of our everyday life (Orion 2019, Herrington et al. 2024). Geosciences have been experiencing a global downward trend for several years, which is reflected in the number of students and workers in geoscience fields (UNESCO 2023, Rogers et al. 2024), the omission of earth sciences from formal teaching in schools (Georgousis et al. 2021, Yusof et al. 2021), as well as the general lack of interest of the general public in geology (Rogers, 2024). However, to reverse this trend, it is not enough to promote geosciences and their study as such, but to educate the public about the Earth and its processes, starting with elementary information that they may not have, given the level of formal education.

The popularization of geology and environmental education is a cornerstone for shaping children and their attitudes in this matter (Orion 2019, Stolz & Megerle 2022), which could positively influence their interest in geology and future decisions. Geotourism, as a sustainable form of tourism focused on geology and environmental education, appears to be an effective tool in this regard (European Federation of Geologists, 2023; UNESCO 2015) A foundation in geology, education, sustainability, tourist satisfaction, and regional development represent the key principles of geotourism (Newsome & Dowling 2010). Therefore, if we speak about education in geotourism, we are talking about sustainable recreational education, which is attractive and interesting for tourists and can also benefit local residents. However, to educate the general public, it is necessary not only to provide information but also to interpret it appropriately. The interpretation of the geological heritage thus represents the communication of information about the given heritage and its origin in such a way as to acquire knowledge, induce a particular emotion, and positively change the tourist's attitude (Macadam 2018, Ren et al. 2013). In case the information is misinterpreted the tourist simply does not understand the information or decides to ignore it, which, in the end, means it does not lead to the education what was the primary goal, to begin with. Based on works of Stolz & Megerle (2022), Ren et al. (2013), Macadam (2018), Štrba & Palgutová (2024) it was possible to define some benefits that an effective geo-interpretation has, such as

a) educating the general public about the geological heritage and its origin representing its formation, evolution, processes leading to it, and/or impact it has/had,

b) representing a tool of informal education and therefore filling the missing gap in formal education,

c) popularizing earth sciences and initiating a positive trend,

d) protecting the geological heritage by communicating its value and creating an emotional bond with the tourist,

e) increasing the attractiveness of the location where the geological heritage is located and improving the quality of the visit experience for tourists,

f) involving local inhabitants in its creation and mediation which supports the development of the region.

Effective interpretation of geological heritage in geotourism is essential for fulfilling educational objectives and bridging the gap between science and the public. However, it is often executed without adequate planning and development, resulting in unmet visitor expectations.

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Holocene high-energy event periodicity in the Tatra Mts. (Western Carpathians)

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The comprehensive paleolimnological investigation conducted on the southern (Slovak) side of the Tatra Mts. between 2016 and 2021 revealed organic sedimentation became dominant facies, dated back to 12.2 ka. Dark brown-grey gyttja can contain up to decimetre-thick intervals of lighter silty and sandy laminae. These intervals are also marked by a rapid increase in CT-number values and contain damaged chironomid head capsules. The silty (and rarely sandy) minerogenic laminae are interpreted as distal records of debris flows deposited during the final stage of flow, as turbulent flows initiated by subaquatic gravitational sorting of debris flow sediments, or as suspended loads of extreme fluvial inputs. However, only high-energy processes can transport clastic (mostly fine-grained) material to the distal part of the lake. These silty laminae concentrate to the periods of 10.6–7, 5.5–3.7, 2.8–2.3, and 0.6–0.3 cal kyr BP in the Nižné Temnosmrečinské pleso. The Popradské pleso reveals several periods of fine clastic input, with the most pronounced occurring during 8.9–7.6, 3.8–1.8, and 1.5–0.3 cal kyr BP. This comparison suggests that the distribution of laminae, as records of high-energy events, is specific to the valleys in which the lakes are located and the extreme floods are asynchronous events in individual valleys. However, if clastic input frequencies are compared among the valleys, it is possible to identify time periods of minimal and elevated activity of high-energy events. The high-energy events most often occurred during the dry periods in the Tatra Mts. with the dry conditions serving as preparatory factors for weathering and accumulation of clastics.

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Educational potential of decorative and building stones

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Natural building stones are defined according to EN 12670 (2001) as natural resource rock with use in construction and for the restoration and reconstruction of monuments. They can be used as load bearing elements or for ornamental and decorative elements, e.g. cladding panels or sculptures. *Decorative (ornamental) stones* are natural building stones used for aesthetic purposes in construction and monumental sculpture.

City centres offer on a small area an excellent opportunity to study both the *historical* and *modern architecture* together with their building, especially decorative stones, which allow you to arrange an attractive, low cost, time-consuming *geological excursion* that combines *geological knowledge* with both *technical* and *artistic* disciplines. The excursion great advantage can be the possibility of seeing petrographically variable and interesting *rock types* in a short time. The decorative stone comes from various *geological units* ranging from old cratons through orogenic belts to platform covers. They can combine the knowledge from geological sciences, such as *physical geology* (geological process), *petrography* (rock types), *mineralogy* (mineral composition), *palaeontology* (fossils), *historical geology* (rock age) and *regional geology* (geological unit) with *geography* (locality), *building history* and *architecture*, *aesthetic education* and *stonemasonry* (methods of stone processing and placement). Excursions can be done for pupils and students at all school levels as well as for the public (Pivko 2001, 2005b, c).

Slovak cities with more than 50,000 inhabitants have enough types of stones on buildings in their centres, approximately from 25 to 50, to make it possible to arrange a geological excursion.

Most problematic point at excursion arrangement is the stone identification, because the excursion guides almost do not exist. Some *excursion disadvantages* are "greenhouse conditions" at visual rock perception and cognition, because of not real stone appearance in polished tiles compared with natural outcrops. Planned route does not correspond to reality over the years for some building can be destroyed or rebuilt.

Castles, manor-houses, churches, monasteries, cemeteries and *sculptural monuments* outside of cities usually offer several types of building stones. Historical buildings connect historical value with interesting natural stones especially from city surroundings – local geology, sometimes present stones which are not more visible in natural outcrops or quarries.

During the Roman Times and the Middle Ages, the stonemasons used almost exclusively porous, soft stones which were easy worked to products. The most used stones in Slovak territory were sandstones, porous limestones, pyroclastic and epiclastic rocks. From the 13th century and mainly from the 17th century, interior polishable stones were used such as compact limestones and marbles.

The contemporary public buildings as opposed to historic buildings present large amount of polished stone tiles, exotic rocks from all over the world on which variable structures (e.g. bedded, banded, veined, brecciated, porphyritic), minerals (e.g. feldspars of different colours, quartz, garnet, various dark minerals) or fossils (e.g. ammonite, orthoceras, belemnite, sponge, bivalve, nummulite, algae and crinoid) are very visible. The decorative stones used in contemporary buildings come from over 30 countries, most of Italy, India, Chine, Brazil, Spain, South Africa, Finland and Czech Republic. Among *magmatic rocks* there are granite, granodiorite, syenite, gabbro, charnockite and dolerite, among *metamorphic rocks* migmatite, marble, gneiss, granulite, slate and quartzite, among *sedimentary rocks* limestones of various periods and types (e.g. algal, rudist, nummulite, micrite, coral, nodular or crinoid limestones), travertine, onyx marble, sandstone, conglomerate and shale.

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Internal structure and characteristics of several low altitude-mid latitude talus deposits affected by chimney effect (Romanian Carpathians)

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Low altitude, mid latitude talus deposits are relict and sometimes openwork landforms developed in past colder climates. Nowadays they are located below the alpine altitude level in the forest belt. Some of them are often overcooled as a consequence of continuous ground air circulation imposed by different density of inside air in comparison to the atmospheric air (Delaloye et al, 2003). This effect is known as the chimney effect and may allow for low altitude permafrost occurrence even in conditions of mean annual air temperatures well above 0 °C (e.g. Gude et al. 2003, Morard 2011, Raska et al. 2011, Stiegler et al. 2014). Such a site was identified in Romanian Carpathians at Detunata from Apuseni Mountains (Popescu et al. 2017). The aim of this work is to investigate the internal structure of several talus slopes from Romanian Carpathians by geophysical and drilling methods and to verify if the phenomena of cold screes are widespread in Romanian Carpathians by field observations and thermal survey. The main study site is Detunata Goală (Apuseni Mountains) along with other three granitic and one calcareous talus slope from Southern Carpathians. The research questions that we attempt to respond are: i) how deep are the taluses? ii) What is their stratigraphy? Is there perennial ice underground? What drives ground air flowing by chimney effect?

Detunata Goală (DG) is a basaltic ridge (peak at 1158 m asl) resulted from a lava flow of Neogene age dated to 7.4 Ma (Roşu et al. 1997) with impressive talus slopes accumulated at its base. Jieț taluses (J1, J2 and J3) are located on a lower part of a glacial valley between 1280 – 1420 m asl in Parâng Mountains while Buila talus (B) is located at 1130 m asl in a non-glaciated mountain. Forest surrounds all these screes.

At all sites electrical resistivity topmography revealed high resistivity anomalies of the openwork talus layer on the order of 40-100 KΩm while the bedrock exhibited lower values. Seismic refraction applied at Detunata indicated low P wave velocities at the surface and gradual increase below 15 m. These results indicated that the DG and J1, J2 and J3 are around 8-15 m deep while lower depths (6-7 m) were encountered in B talus. Drilling in DG talus confirmed the 12.4 m thickness and revealed a homogeneous grain size with thin ice lenses from 3.2 to 8.6 m. Continuous thermal monitoring from October 2021 to September 2024 in borehole using temperature data loggers indicated persistent freezing conditions at 7 m with temperature close to 0 ºC all year round and thawing and warming trend starting with winter 2023/2024 probably due to atypical warm winter. SRT indicated that it is difficult to identify thin ice lenses using only ERT in high porosity layer which is also very resistive. Continuous thermal investigations using temperature data loggers at all taluses indicated that D, J1, J2 and J3 are indeed cold screes affected by chimney effect while B talus is not. The main cause might be related to the lower depth of the talus and to the probably consolidated debris layer that does not allow for ground air circulation. Our study indicates that cold screes are not exceptionally rare but they might be widespread across the entire Carpathian Mountains.

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The Western Carpathians Variscan Orogen: A collage of post-Cadomian, Cenerian, and Paleotethyan complexes from the Gondwana-derived terranes (a new concept)

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This study reports the origin and evolution of the Western Carpathians pre-Variscan basement rocks affected by the Variscan Orogeny. In this new concept, we distinguish post-Cadomian (~550-500 Ma) and Prototethyan subduction-accretion (Cenerian; ~500-400 Ma) forearc-arc-incipient backarc complexes from Paleotethyan rift-related complexes (~400-360 Ma), all sited on the northern Gondwana margin (Galatian) terrane close to the Cadomian Ediacaran magmatic arc and distant to the Saharan Metacraton.

The southvergent **Early Variscan structure (~400-360 Ma)** of the Western Carpathians basement includes from top to bottom and north to south: (1) The Upper Unit, composed of higher-grade metamorphics of the Jarabá Complex (~Cambrian-Silurian/earliest Devonian) with the Layered amphibolite-gneiss Complex (LAGC, late Cambrian-Ordovician) at the base. (2) The Middle Unit micaschist-gneisses of the Hron Complex (Cambrian-Early Ordovician?). The Upper Unit represents a northern Gondwana active continental margin (the Galatian terrane in Putiš et al., 2009), whereas the Middle Unit is a passive Gondwana margin. Both units occur in the Cretaceous Tatric and Veporic zones (Plašienka et al. 1997, Putiš et al. 2021). (3) The accreted Gemeric Zone Lower Unit consists of late Cambrian-Ordovician active Gondwana margin Gelnica Complex (Vozárová et al. 2010), which is overlain by the Devonian Rakovec-Klátov Complex of the Paleotethys and the associated continental margin Ružín and (Veporic) Hladomorná Dolina-Klenovec complexes in the southvergent **Late Variscan structure (~360-340 Ma)** (Putiš et al. 2008, 2023). In addition, the low-grade ophiolitic (Pernek, Čierna Lehota) and non-ophiolitic (Pezinok, Kuchyňa, Hlavinka) Devonian complexes overlie the Upper Unit in the Tatric Zone (Ivan et al. 2001, Ivan & Méres 2015. Kohút et al. 2006).

Model for the evolution of the pre-Variscan complexes of the Western Carpathians basement (Putiš et al. 2009) shows their connection with the Gondwana Supercontinent (e.g., von Raumer et al. 2013) in the early Paleozoic. The prevailing Neoproterozoic detrital zircon populations in the Upper and Middle units metasediments of the Tatric and Veporic basement suggest a **proximity to Cadomian Ediacaran magmatic arc** (Kohút et al. 2022, Putiš et al. 2023, Soejono et al. 2024). Less frequent Archean and Paleoproterozoic zircon populations derived from the reworked West African Craton and the Saharan Metacraton (Linnemann et al. 2008), whereas the Gemeric Gelnica Complex metasediments, with rare Mesoproterozoic detrital zircons, may indicate derivation from a terrane close to Amazonia (Vozárová et al. 2010). Despite the Cadomian basement rocks being obscured, km-thick **post-Cadomian** sedimentary sequences in all three Variscan units can be viewed as the response to **late Cadomian** closure and exhumation of the Cadomian Ediacaran arc due to late Neoproterozoic to early Cambrian Cadomian Orogeny (Linnemann et al. 2007).

The lower part of the Upper Unit is built of the **Layered amphibolite-gneiss Complex (LAGC)**, previously termed the Leptyno-amphibolite Complex (e.g. Hovorka & Méres 1993). The LAGC consists of paragneisses intruded by late Cambrian to Ordovician gabbroic rocks, minor peridotites, and granitic to tonalitic rocks. The predominant Neoproterozoic detrital zircons in gneisses provided the Ediacaran concordia ages between 607±10 and 558±7 Ma (Putiš et al. 2008, 2023). The Mesoproterozoic sources are rare, but the Paleoproterozoic to Archean ages between 2.0 and 3.4 Ga were detected by Putiš et al. (2008, 2023). It is supposed that the **post-Cadomian passive Gondwana margin,** represented by thick pelitic-psammitic (meta)sediments, was underplated by late Cambrian to Ordovician mafic-ultramafic rocks in an arc-backarc system (Fig. 1) above a south-directed Prototethys oceanic subduction zone (Putiš et al. 2009, Neubauer et al. 2022). The host paragneisses of the North-Veporic region contain late Cambrian (Furongian) peraluminous Grt-rich granitic and tonalitic orthogneisses (~490 Ma; Putiš et al. 2008, 2009), which formed by melting of the thick post-Cadomian sedimentary-magmatic sources. The peraluminous granitic protoliths of the orthogneisses have a calc-alkaline character, indicating arc-type magmatism. The paragneisses of the lower part of the LAGC contain WP-type alkaline gabbros and minor MORB, derived from predominant enriched mantle sources ($\varepsilon Nd_{(500)}$=+7.7 to 0.0, $TDM_{(2st)}$ 0.58-1.18 Ga). In contrast, the upper part of the LAGC consists of 200-300 m of MORB-type layered gabbros ($\varepsilon Nd_{(480)}$=+10.1 to +5.5, $TDM_{(2st)}$ 0.37-0.73 Ga), which originated by fractionation of juvenile and isotopically homogeneous depleted mantle sources (Putiš et al. 2023). Basaltic and felsic bimodal magmatism lasted from the late Cambrian up to the Late Ordovician (~510-450 Ma; Putiš et al. 2008, 2009), and was likely related to magmatic underplating and melting of the overheated thinned continental crust. The LAGC may have thus experienced an Alaskan type subduction-accretion orogeny during the **Cenerian event,** similar to that reported by Zurbriggen (2020 and references therein) from the Strona-Ceneri Zone of the Southern Alps for the period of 490-440 Ma. Further indicators of the Cenerian event are Grt-And late Cambrian tonalitic orthogneisses, which are partly replaced by the Variscan Ky-Grt-bearing sheared margins in association with eclogite lenses in the North-Veporic area. Such a LP and HT metamorphism excludes collisionally thickened continental crust and implies an orogen overheated by underplated mantle-derived magmas (Cenerian type orogen by Zurbriggen 2020, Siegesmund et al. 2023). Inherited Neoproterozoic and older zircon crystals in HT orthogneisses show the signatures of partial dissolution and crystallization of newly formed Ordovician euhedral outer rims. Similar features are observed on detrital zircons in the hosting paragneisses. Magmatic monazite and xenotime populations of Ordovician age were detected in these orthogneisses by Ondrejka et al. (2016), whereas Petrík et al. (2024) linked them to Ordovician metamorphic overprint.

The LAGC is southvergently overthrust by a few km thick succession of paragneisses with rare calc-silicate rocks, amphibolites, and orthogneisses of the **Upper Unit Jarabá Complex**. The post-Cadomian deposition of this complex may have lasted until the Silurian/earliest Devonian in a forearc setting (Fig. 1). The Neoproterozoic (concordia ages between 572 and 552 Ma; Putiš et al. 2023) and older detrital zircon populations are completed by the Cambrian-Ordovician zircon population derived from the aborted late Cambrian-Ordovician arc-incipient backarc system, the latter limiting the maximum deposition age. This evolutional stage is consistent with an outboard directed supra-subduction compression, exhumation, and erosion of the acidic (orthogneisses) and mafic (metagabbros) type magmatic rocks from which the released zircon was transported to the forearc. However, the Kokava type metamorphosed iron formation of the South-Veporic basement (Konečný et al. 2011) may indicate **Late-Cenerian** shallow shelf forearc sedimentation of the Jarabá Complex.

Detrital zircons in the underlying **Middle Unit Hron Complex** micaschist-gneisses with obtained Neoproterozoic concordia ages of 622±7 and 568±6 (Putiš et al. 2023), indicate an Ediacaran magmatic arc with sources from the West African Craton and Saharan Metacraton provenances.

Early Variscan northward LAGC subduction was dated at 394±5 Ma by Putiš et al. (2023) from an eclogite (Janák et al. 2007; Michálek & Putiš 2009). The LAGC subduction in the retroarc stage (Fig. 1) is nearly contemporaneous with the opening of the **Paleotethys oceanic basin on the northern Gondwana margin**. The Devonian coupled Rakovec-Klátov Complex of the Gemeric basement is representative of the Paleotethys rift-related basin (Grecula 1982, Putiš et al. 2009, 2023, Radvanec et al. 2017). The small scale of LAGC northward subduction probably did not provide sufficient slab pull for Paleotethys opening. Alternatively, continuing Prototethys subduction beneath the Cadomia-Galatia terranes was most likely the main triggering force for Paleotethys opening, possibly initiated by a mantle plume. This hypothesis is supported by the arc-type Middle-Devonian calc-alkaline granites to diorites of the Ružín Complex (zircon $\varepsilon Hf_{(390)}$=+9 to -13) and the rift-type WP alkaline tholeiitic basalts of the Rakovec Complex ($\varepsilon Nd_{(400)}$=+8.2 to +3.7, $TDM_{(2st)}$ 0.46-0.81 Ga) that terminated with the Klátov Complex MORB formation ($\varepsilon Nd_{(400)}$=+9.8 to +5.4, $TDM_{(2st)}$ 0.34-0.68 Ga) in a nascent oceanic BAB (Fig. 1). This Paleotethys branch was closed by northward subduction in the Early Carboniferous (350±5 Ma metamorphic zircon age) followed by the accretion of the Lower Unit complexes to the coupled Upper and Middle units. The Late Devonian BAB Pernek Complex (Ivan et al., 2001) may have also formed due to southward Prototethys oceanic subduction beneath the Early Variscan Orogen Upper and Middle units separated by the LAGC suture. The Pernek Complex ($\varepsilon Nd_{(370)}$=+10.4 to +8.0, $TDM_{(2st)}$ 0.27-0.43 Ga) and other Paleotethyan complexes were included in the **Late Variscan Orogen**.

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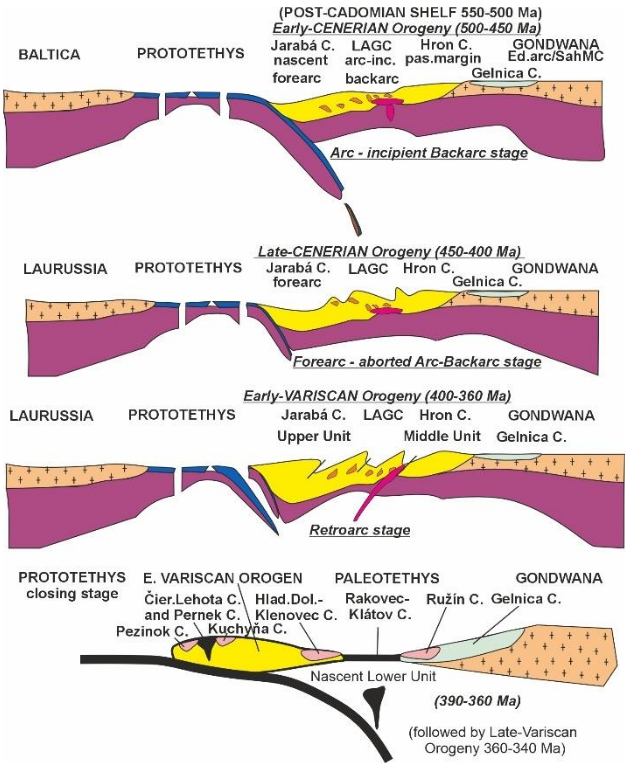

Figure 1: Evolution of the Western Carpathians basement. See explanation in the text.

Jurassic/Cretaceous (J/K) – Tithonian/Berriasian Boundary and Berriasian/Valanginian Boundary - the Global Boundary Stratotype Section and Point (GSSP) – state of the art

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Formal definition of the Jurassic/Cretaceous (J/K) or Tithonian/Berriasian (T/B) boundary is still a matter of debate (Wimbledon et al. 2020; Enay 2020). The approach of new Berriasian Working Group (BWG) is to put the T/B boundary in the Tethyan domain, where complete chronostratigraphic record is available between the Late Tithonian and earliest Valanginian supported by integrated calpionellid, calcareous nannofossil and magnetic stratigraphy (Casellato & Erba 2021). The opinion of the former BWG that ammonites should be regarded rather as useful but not a first-order marker in defining the J/K boundary, at least in the Tethyan domain is still accepted. The crucial areas for global correlation remain: Sub-Boreal and Boreal basins of NW Europe and Arctic, Southern America, as well as Russian and Siberian domains.

The BWG selected potential horizons for correlation with shallow marine and terrestrial environments, as well as with other palaeogeographical domains:1) still actual J/K boundary at the base of *Calpionella alpina* Subzone (base NC0 nannozone, within M19n2n magnetosubzone); 2) The boundary situated in the middle Berriasian - base of *Calpionella elliptica* Subzone which approximately correspond to the base of NC1 nannozone and the base of magnetozone M17r and, being close (probably slightly older) to the base of Occitanica Ammonite Zone and middle Berriasian transgression in the Jura Mts and the Volgian/Ryazanian boundary; and 3) J/K boundary situated in the upper Tithonian – the base of *Crassicollaria intermedia* Subzone of the standard *Crassicollaria* Zone correlating with NJT17 calcareous nannofossil zone (between magneto(sub)chrons M20n1r and M19r). This interval is easily recognizable in Western Tethys, through bioevents mentioned above as well as important palaeoecological trends: nannofossil calcification event (Bornemann et al. 2003), demise of *Saccocoma* microfacies (Grabowski et al. 2019) and change of calpionellid lorica structure (Reháková & Michalík 1993). Correlation with Neuquén Basin (Argentina) is easier in the Upper Tithonian than in the Lower Berriasian, due to robust magnetostratigraphic data and good consensus concerning ammonite stratigraphy (Aguiree-Urreta et al. 2019; Kietzmann et al. 2021). Comparing Siberian and Russian proxies (Schnabl et al. 2015, Rogov et al. 2015) the interval might correspond either to the Middle/Upper Volgian boundary or to the Okensis/Tajmyrensis (Subditus/Nodiger) ammonite zonal boundary in the Upper Volgian. The weak point here is an uncertain stratigraphic position of the Okensis/Tajmyrensis boundary against magnetostratigraphic scale in Nordvik section (between M19r and middle M19n magnetozone).

The position of the Portlandian/Purbeckian (P/P) boundary in the southern England, traditionally set at the top of Anguiformis ammonite Zone remains still problematic. Late Tithonian palaeoenvironmental aridification and regression trends thorough the P/P interval were correlated with related intervals in the Tethys realm (Grabowski et al. 2021; Błażejowski et al. 2023). Different concepts of correlation between English and Russian-Siberian ammonites (Wierzbowski et al. 2017, Wimbledon et al. 2020) exist. Taking them into account, the P/P boundary could be situated between the uppermost part of M20n2n and lowermost M19n2n magnetosubchron, with an uncertainty interval of ca.1 My. Because the position of the Okensis/Tajmyrensis ammonite zonal boundary is still not well resolved (Schnabl et al. 2015), Purbeckian base could be as high as in mid-M19n magnetozone, coinciding rather with the base of Alpina Subzone, the present-day position of the T/B boundary.

The Torre d´Busi section situated in Lombarian Basin of NE Italy is actually considered as one of possible GSSP candidates.

According to the formal voting process that occurred in May 2024, the Valanginian Working Group (VWG) has officially approved the Vergol section, located in Montbrun-les-Bains (Drome, France), as candidate for the Global Boundary Stratotype Section and Point (GSSP) and Cañada Luenga (Cehegín, Murgia region, SE Spain) as its Standart Auxiliary Boundary Stratotype (SABS), using *"Thurmanniceras" pertransiens* (ammonite) as the primary marker to define the Valanginian base. At Vergol, the First Occurrence (FO) of this index-species is recorded in bed VGL-B136. In addition to the primary marker, a series of secondary biostratigraphic events of inter-regional correlation value is provided in order to characterize the interval around the Berriasian/Valanginian boundary at the Vergol candidate section. Thus, it can be noted the FOs of calpionellid species as *Calpionellites darderi* and calcareous nannofossil species as *Calcicalathina oblongata.* The formal proposal (Reboulet et al. 2024) was submitted to the Subcommission on Cretaceous Stratigraphy (SCS) of the International Commission on Stratigraphy (ICS), in order to be the basis of a formal ballot on the proposal of a GSSP for the base of the Valanginian. The SCS approved GSSP proposal in August 2024 and submitted it to International Commission on Stratigraphy (ICS) for formal voting.

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Badenian / Sarmatian boundary detected at the south-west slopes of the Devínska Kobyla hill (Bratislava, Vienna Basin)

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The research at the Meszároš site located ca. 700 m southwest of the Dúbravská Hlavica (48.179985°, 17.008030°) was conducted as part of a field course of the Department of Geology and Paleontology in 2022–2023. This research brought noteworthy information about the paleoecology and biostratigraphy of the sediments at the Devínska Kobyla hill, a location of great geological importance. The sediments of the studied area were assigned to the Studienka Formation (Bulimina/Bolivina Zone) based on foraminiferal associations, and to the NN6 Zone based on the nannofossils (Hyžný et al. 2012, Jamrich et al. 2024, Kováč et al., in press).

The site is formed by several outcrops in the ditch, consisting of coarse- to fine-grained marine sediments. The created composite outcrop is ca. 3.5 m high.

At the base 70 cm thick gravelly sandstone packed in decalcified macrofossils (mollusks) is present. This layer is the most probable source of the scree in which most of the macrofossils were found. Higher up 150 cm thick fine-grained sand, barren in macrofossils occurs. In the lower part it is intercalated by a 25 cm thick layer of oyster-specimen-rich (*Cubitostrea digitata*) fine-grained sand. Above it a 20 cm thick layer of very coarse-grained conglomerate (cobbles up to 25 cm in diameter) occurs, possibly interpreted as a result of a catastrophic event. The following interval (60–110 cm) is characterized by an alternation of very fine-grained and fine-grained sandstones. Upwards (110–240 cm) follows a very fine-grained sandstone body, which is interrupted by ca. 10 cm coarse-grained sandstone. The upper part of the outcrop is formed by an erosion boundary and continued by ca. 10 cm slope debris followed by forest soil.

The locality is rich in fossils, dominantly consisting of decalcified molds of fossil mollusks (e.g., *Thracia* sp., *Linga* sp., *Archimediella* sp.) and shells of pectinid bivalves (e.g., *Flabellipecten leythayanus*) and oysters (*Cubitostrea digitata*) as well as rare finds of fish (*Sparidae* indet.) and ray (*Aetobatus arcuatus*) teeth, documenting shallow marine environment. On the contrary, finds of bones and shell fragments belonging to several turtle specimens (?Testudinoidea indet., ?*Testudo* sp.) point to a terrestrial environment's proximity with a freshwater source.

This typical, diversified marine upper Badenian association of mollusks and foraminifers is replaced by the early Sarmatian assemblages represented by specific keeled elphidias (e.g., *Elphidium josephinum*) and the onset of the *Anomalinoides dividens,* an index taxon for the regional biostratigraphy of the Paratethyan area (Cicha et al. 1975). The change in foraminiferal assemblages could possibly indicate either a gradual transition from a normal marine

(Badenian) to a hypersaline (Sarmatian) environment or a cyclic fluctuation of water chemistry in this area. Hence, sediments of Meszároš locality can be correlated with nearby localities (Dúbravská Hlavica, Pektenová lavica and Fuchsov lom) of similar biostratigraphical and paleoecological development.

Therefore, sediments of this marginal marine locality with terrestrial fossil components are classified to the transition interval between the upper Badenian Studienka Formation and lower Sarmatian Karlova Ves Formation.

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Paleovolcanic reconstruction of the geological structure in the northwestern part of the Central Slovak neovolcanites

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The geological structure of the territory in the northwestern part of the Central Slovak neovolcanites represents a complex volcanic structure with a temporal and spatial suite of superimposed volcanic structures (Šimon & Lacika 2022). The dominant structure of this area is the Kremnica graben formed in Baden. Before the formation of the Kremnica graben, an important andesite Kremnica stratovolcano was formed. Its products come to the surface in the area of the uplifted Kremnica peat deposited in the space of the Kremnica graben as well as outside the graben on its eastern and western sides. In the central volcanic zone of the Kremnica stratovolcano, it represents a complex of bedded intrusions of metamorphosed rocks with relics of lava flows, volcaniclastic rocks and andesites. The base of the central volcanic zone of the Kremnica stratovolcano is formed by subvolcanic bodies of diorites and diorite porphyries. At the same time, the massive Štiavnica stratovolcano of the Baden age intervened in the area with its distal volcanic zone. In this area, at the foot of both stratovolcanoes, a thick assemblage of epiclastic volcanic conglomerates, sandstones and also tuffs, pumice tuffs, agglomerates and phreatopyroclastics with a thickness of up to 200 m was deposited in a fluvial-limnic environment. In the overburden, the assemblage passes gradually into the Handlov assemblage, which represents coal seams with clay-tuffite succession. The thickness of the formation ranges up to 50 m. The Košianske assemblage is deposited on the Handl and Nová coal assemblages and is monotonous dark gray to greenish gray clays and calcareous clays. As a result of abrupt block tectonics and denudation, the current thicknesses of the formation vary from a few meters to 300 m in subducted blocks. The Novolehotská formation represents manifestations of rhyolite volcanism in the form of rhyolite bodies. The age of 14.3 ± 0.7 million was obtained by radiometric dating of rhyolite using the K/Ar method. years corresponding to the Upper Baden. Subsequently, extrusive volcanism of hypersthenic-amphibolic andesites of the Plešinsk Formation was formed. The Lehot Formation is deposited on the surface of the Košian Formation modeled by erosion. The Lehot Formation consists of irregularly alternating poorly sorted fine to coarse gravels and sands with material of Mesozoic carbonate rocks and quartzites, less granites, crystalline slates and Paleogene sandstones, rarely andesites. The thickness of the formation is very variable from a few tens to 300 m. The immediately following development of the Kremnica graben caused dramatic changes in the paleogeography of the area. The middle structural floor of the territory is formed by the filling of the Kremnica graben. The development of the Kremnica graben in the Upper Baden to Lower Sarmatian period took place as a result of subsidence of a relatively large area, which included the central part of the Kremnica stratovolcano, the area of the Žiarska basin up to the northern edge of the Štiavnica stratovolcano, and including the eastern part of the Vtáčnik mountain range. The subsidence took place along massive fault zones in the direction NE-SWZ to N-S with an amplitude of

subsidence of more than 1000 m. The initial stage of subsidence was accompanied by volcanism of pyroxenic andesites. The products of this volcanism are represented by the Kľakovská dolina formation. The formation consists of phreatomagmatic pyroclastics at the base, lava flows of pyroxenic and leucocratic andesites and epiclastic volcanic rocks are found above. In the upper part there are also deposits of pyroclastic rocks. The uppermost part of the formation consists of extrusions and lava flows of basaltic andesites. Dating by the K/Ar method on rocks in the interval 13.2 – 14.4 Ma points to the upper Baden to lower Sarmatian. The upper part of the filling of the Kremnica graben is mainly formed by the products of explosive-effusive volcanism of pyroxenic andesites to amphibolic-pyroxenic andesites, represented by lava flows, extrusions, dykes and pyroclastics, which are represented by the Stern Formation. The formation occurs in graben blocks west of the Žiarska basin and is built by dominantly andesite lava flows up to 300 m thick. Based on the positional relationships, the Stana formation is included in the Upper Baden to Lower Sarmatian. In the Sarmatian period, as a result of the new ascent of magmas into the surface reservoirs and the processes of their differentiation into andesitic magmas, several smaller satellite volcanoes were formed at the edges of the Kremnické graben, on the southeastern slopes of the Kremnické vrchy and in the western part in the Vtáčnik area. The Remat volcano was formed on the northwestern slope, whose relics are represented by the Remat formation on the territory. In the northwestern part, the Vtáčnik statovolcano arose, whose relics are represented by the Vtáčnik formation on the territory. The current volcanic structure of the remains of the stratovolcano is characterized by a pronounced asymmetric character. The western part of the original stratovolcano was preserved, while its eastern part was removed by denudation and this progressed to the area of the central volcanic zone.

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Biostratigraphy *vs.* tephrochronology in determination of the Eocene/Oligocene boundary in the Central-Carpathian Paleogene basin.

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A high-resolution planktonic biostratigraphy and tephrochronology has been integrated to define the Eocene/Oligocene boundary in the Central-Carpathian Paleogene Basin (CCPB). The study was focused to boundary sections with planktonic bioevents and volcanic ashes for geochronological dating. Such pronounced boundary section with tuffite horizons occurs near Istebné in Orava region. The lower part of the Istebné section dominates by non-calcareous claystones with deep-water agglutinated foraminifera. Their middle Eocene age is constrained by the presence of *Ammodiscus latus* (cf. Waśkowska & Kaminski 2012). Plankton-rich hemipelagic intervals contain foraminiferal species *Hantkenina alabamensis*, which last occurrences marked the E/O boundary (cf. Coccioni 1988). The tuffite horizons in the Istebné section provide the U-Pb zircon age 32.98 ±0.18 Ma (Fig. 2), which corresponds to the E/O boundary in the GTS2020 (33.9 Ma, cf. Speijer et al. 2020). Moreover, the boundary tuffite beds also correspond to "Tuff 25" dated around 32,8 – 34.6 Ma in the Outer Western Carpathians (cf. Van Couvering et al. 1981).

Above the E/O boundary, the Istebné section reveals a considerably changes in productivity and dwarfing of planktonic foraminifera. Beside of rich small-sized forms of *Globigerina*, *Tenuitella* and *Chiloguembelina,* a new species of *Dentoglobigerina* (*D. tapuriensis*), *Turborotalia* (*T. ampliapertura*) and *Paragloborotalia* became to appear. Simultaneously, the agglutinated foraminifers were highly impoverished in responce of the Oligocene climatic cooling (cf. Ortiz & Kaminski 2012).

The E/O boundary is also indicated by calcareous nannofossils. This boundary is predated by first appearance of *Isthmolithus recurvus* in the NP19/20 zone and characterized by co-occurence of *Lanternithus minutus* a *Zygrhablithus bijugatus* (Nyerges et al. 2021). The base of the Rupelian is marked by nannofossils of the NP 22 zone, like species *Helicosphaera bipuncta* and *H. recta*, and appearance of *Reticulofenestra ornata* in the NP 23 zone. The climatic index taxa of the calcareous nannoplankton imply a decrease of species with warmer preferences (e.g. *S. moriformis*) to species with colder preferences (e.g *Z. bijugatus, L. minutus*).

The results from the Istebné section provide a good correlation with E/O boundary events, like last occurrences of hantkeninids in the Turie section, and tuffite ages of 34.76 ± 0.25 Ma in the Revištné section and 30.76±0.20 Ma in the Šútovo section.

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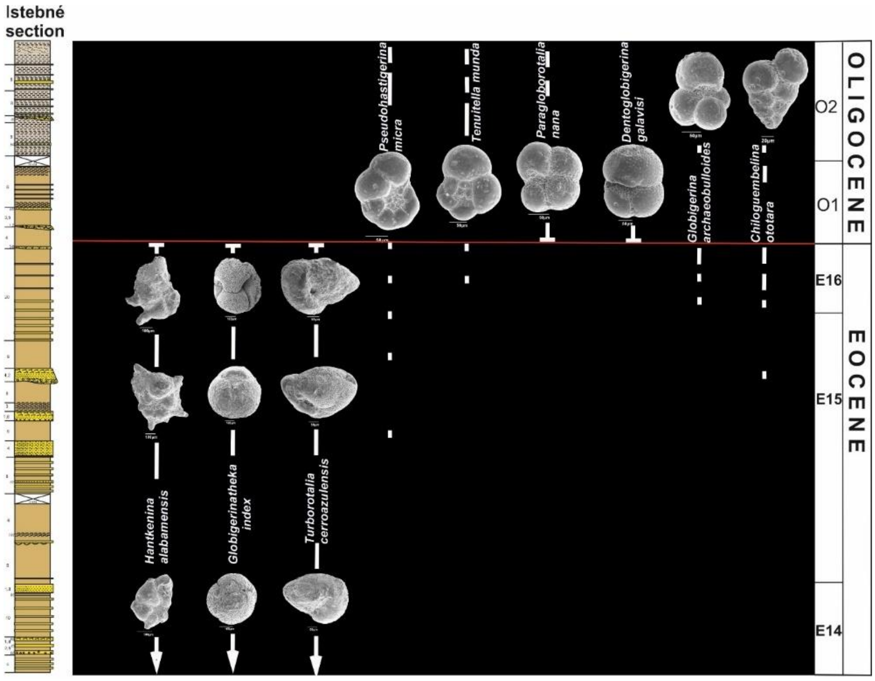

Figure 1: Eocene-Oligocene boundary defined by highest and lowest occurrences of planktonic foraminiferal species in the Istebné section.

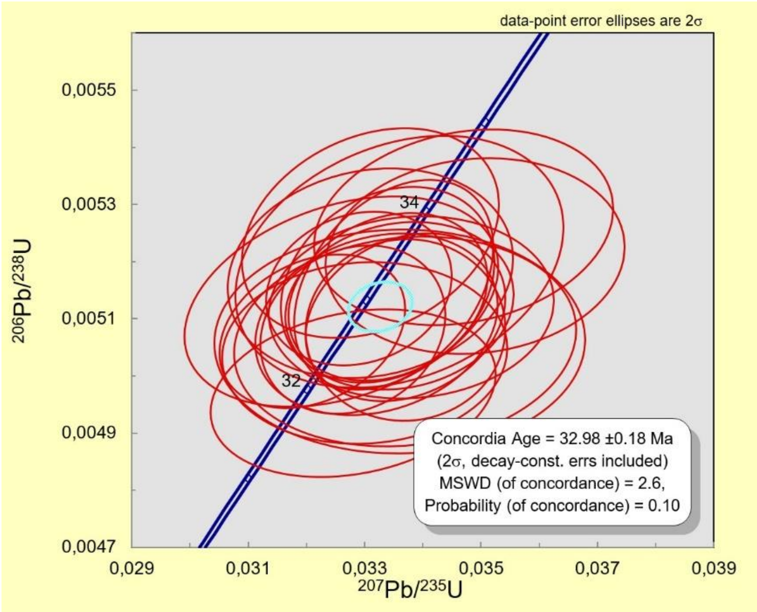

Figure 2: The U-Pb zircon dating of tuffite bed in the Istebné section providing the concordia age of 32.98 ±0.18 Ma.

From Nummulitic breccias to Flysch deposits: Eocene treasure of Central Dalmatia (Croatia)

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Eocene deposits from Dalmatia were disconformably deposited over Cretaceous rudist limestones near the coast of the Western Neotethys (Marjanac,1996, Ćosović et al. 2018). In the Omiš area, Lutetian-Early Bartonian Nummulitic limestones and bioclastic "breccias" are dominantly composed of large orthophragminid genera *Nummulites* and *Discocyclina*. In younger horizons they comprise planktic taxa *Globigerinatheka* and *Subbotina*. Red algae often compose macroids, with *Sporolithon* and *Lithoporella* being the main bioconstructors. They are associated with other coralgal genera (*Mesophyllum*, *Polystrata, Lithothamnion*, *Neogoniolithon* and *Hydrolithon*) and encrusting foraminifera *Acervulina, Solenomeris*, *Placopsilina* and *Nubecularia*, sometimes incorporating the genera *Rotalia* and *Eoannularia* (Sremac et al. 2020, 2024a,b). Less abundant but diverse macrofossils include solitary and colonial corals, bivalves (cockles, oysters, scallops), gastropods (*Columbella* sp.), rhynchonellid brachiopods, rotularian serpulids, crinoids (*Isselicrinus* sp.) and echinoids. Carbonate deposits are overlain with glauconite marls known as Transitional beds and, finally, Flysch deposits (Fig. 1). Grey marls comprise rich and diverse nannofossil assemblages (e.g. the genera *Chiasmolithus, Coccolithus, Corannulus, Discoaster, Reticulofenestra, Sphenolithus)*, pointing to the NP17 and NP18 nannozones (Bartonian-Early Priabonian) (Martini, 1971). Limestone olistoliths, dispersed along the Omiš area beaches, are a part of the regionally developed megabed, connected with the collapse of the platform margin (e.g. Marjanac 1996).

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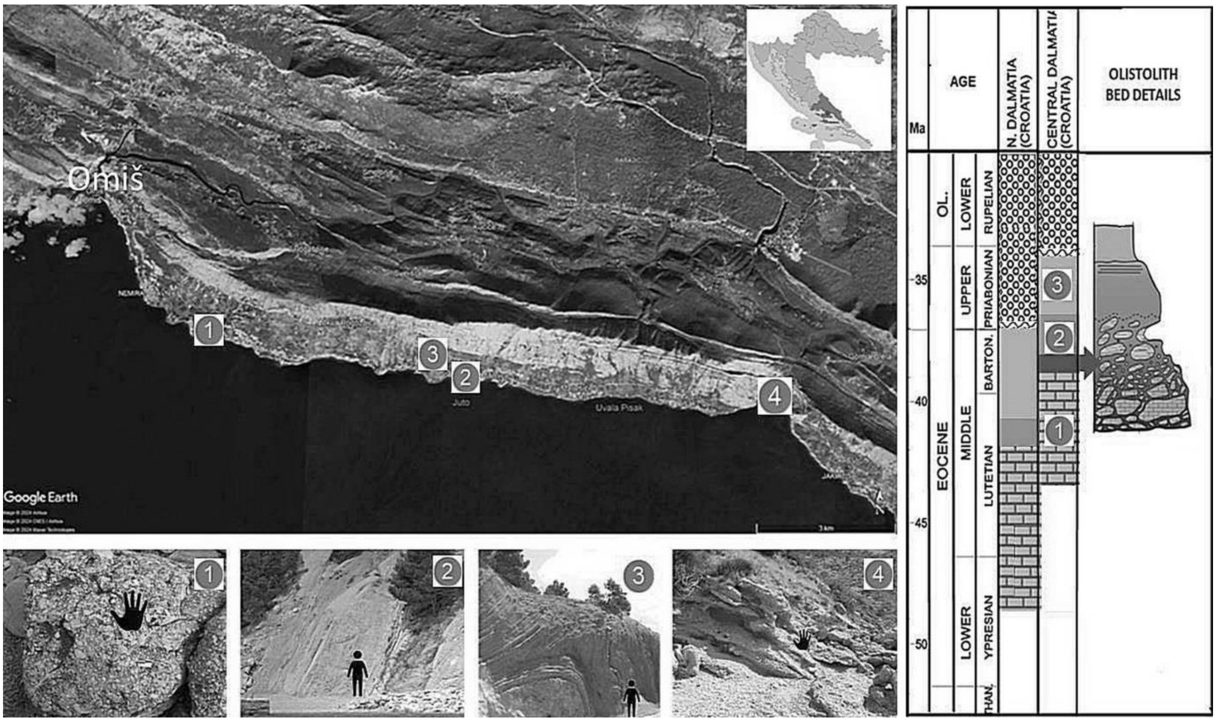

Figure 1: The geographic (Google Earth, 2024) and stratigraphic position of the studied outcrops in the vicinity of Omiš: 1. Nummulitic limestone; 2. Glauconite marl; 3. Folded flysch deposits; 4. Quaternary breccia. Clastic deposition started during the Bartonian, later than in Northern Dalmatia (partly after Sremac et al., 2020, 2024a). Outcrop size is shown by human or palm silhouettes.

Various perspectives of important geological sites perception

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Geological heritage sites, recognised for their scientific importance, are increasingly valued for their diverse contributions to society. In many cases, these sites enable scientists to study Earth's history and understand various processes that contributed to forming specific geological structures, elements or deposits. In this regard, the preservation of such places is crucial as they embody unique geological features, rare mineral occurrences, and fossil records that offer invaluable insights into past environments and life forms.

To effectively manage and protect these sites, various initiatives, including geosite databases, have been introduced (Wimbledon et al. 2000, Liščák & Antalík 2018). Such inventories may contribute to raising awareness of geological heritage sites from various perspectives, highlighting the diverse features of geoheritage. Several geoheritage assessment methods were defined to refer to the specific values and features of geological heritage sites or geodiversity elements and their potential use for various purposes. While geoscientists prioritise sites with exceptional scientific value, educators emphasise those with potential for teaching and learning, and tourists primarily tend to appreciate sites with scenic beauty and recreational opportunities (Štrba et al. 2023). Thus, a single site of unique geological heritage can be considered from various perspectives and not only from the (geo)scientific one.

In Slovakia, the database of important geological sites includes 480 locations (VGL 2012a). As mentioned in the description of the Information System of Important Geological Sites in Slovakia (VGL 2012b), the continuous addition of relevant data should ensure that the database provides up-to-date information to the broad professional public, especially in the field of education, protection and geotourism. Even though, according to the database authors, '*texts are provided at an educational level equivalent to high school students*' (VGL 2012a), the geosites are characterised only by their geological nature and scientific significance. There is a lack of information on the recent state of the main elements, sensitivity and vulnerability, and about the most remarkable properties. Moreover, very limited or no educational and geotourism use characteristics are available, as the inventory of geosites in Slovakia does not identify their potential use for such purposes.

Considering the complex approach to geotourism, especially its ABC concept (Dowling 2013), the current form of the database is not applicable for the determination of key elements (geoheritage sites) in national tourism strategies, for the development of geotourism and use in the framework of sustainable promotion and protection of the territory. Only geosites assessed in this way can increase the impact on society, raise interest in geological heritage and geosciences not only among geoscientists and a relatively small group of enthusiasts but among a much wider audience of the general public, and bring economic benefits when used in geotourism. Therefore, a more holistic approach, taking into account different perspectives and including proper geointerpretation forms, is required when considering using important geological sites for overall raising awareness about geosciences, protection purposes, to promote this part of natural heritage to the general public and use in (geo)tourism as mentioned on the web page of the database.

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Mineralogy of residues from the extraction and processing of mineral resources in Slovakia

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According to the data from the old mining and recent mining works register of State Geological Institute of Dionýz Štúr (SGIDŠ), there are more than 18000 of them (https://app.geology.sk/geofond/sbd/). Mining wastes, in the form of heaps and debris after ore treatment, have remained in the vicinity of agglomerations and infiltrate in various forms into the surrounding environment. As part of the project "Ensuring Monitoring of Environmental Burdens in Slovakia – Part 2 (ZMEZ2)," a total of 40 sites associated with mining waste were monitored. Within this work, 8 sites: Čučma, Dolná Lehota - Lom, Jasenie - Soviansko, Kremnica, Pukanec, Rákoš, Rožňava and Špania Dolina were selected for the investigation of solid materials and their weathering products.

Each site represents a different type of mineralization localized in a distinct geological setting. The objective of this study was to assess the mineralogical and chemical composition of tailings materials at the selected sites. In addition to the collected samples of veins, river sediment, and soil, anthropogenic smelting slags were also analyzed. The analysis of slags was important due to the potential of discovering new phases, as well as due to the limited attention they have received in previous research of e.g. Šoltés et al. (2003), Šoltés (2007), Demko et al. (2015) and Hredzák et al. (2023).

Microscopy of individual polished slides was performed on the Jenapol optical instrument at SGIDŠ in Bratislava. Quantitative chemical analyses (EDS, WDS) of minerals, were carried out on the CAMECA SX100 electron microanalyzer at SGIDŠ in Bratislava. Whole rock analysis was carried out in laboratory of SGIDŠ in Spišská Nová Ves and contained 3 different methods. Silicate analysis was performed on WDXRF S8 Tiger (Bruker). Determination of trace elements on EDXRF SPECTRO XEPOS HE and total organic carbon was measured on TOC Analyzer ANALYTIK JENA MULTI N/C 2100S. Raman spectroscopy included the use of Thermo Scientific DXR microspectrometers at the Comenius University Bratislava and Thermo Scientific DXR3xi in the laboratories of the SNM-Natural History Museum in Bratislava.

Of the primary phases, the sulfosalts zinkenite as well as tetrahedrites are probably the most interesting, and of the Rákoš sulfides ullmannite and cinnabar.

New finding include the occurrence of the mineral phase derbylite from the Dolná Lehota locality, as well as a diverse range of PbMn oxides from the Jasenie locality, primarily comprising cesarolite and various other phases likely formed by coronadite and the Mn-analogue of plumboferrite. Another significant finding from Jasenie is the presence of Pb-rich goethite, with lead contents reaching up to 9.39 wt.%. Other noteworthy secondary phases include jarosite from Pukanec, romanechite from Čučma and cervantites from both Špania Dolina and Čučma localities.

The slags contained a variety of phases, with silicates such as pyroxenes, feldspars and Ca-rich olivines being identified. The AlCaNaF-rich slags from Kremnica contained cryolite, fluorite, corundum and trinepheline, along with the ore phase stilleite, which is the Se-analogue of sphalerite. Pb-rich owensite and samaniite were identified in slags from Špania Dolina and Čučma, respectively. Sulfides were identified in several samples, especially cubanite and members of the talnakhite group including mooihoekite and haycockite. Among the alloys, cuprostibite, seinäjokite, Fe-rich zlatogorite and, notably from the Čučma locality, westerveldite was detected. Raman spectroscopy successfully identified previously unmeasured seinäjokite and cesarolite and captured a spectrum of derbylite.

Each study site contained different primary materials, and as a result, the weathering products were largely influenced by both the composition of materials and the prevailing environmental conditions. For example, weathering of sulfides with complex chemical compositions can release various elements into the environment, potentially leading to pollution. However, these sulfides can also serve as valuable secondary resources for element recovery.

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Geochemical and Mineralogical Analysis of Two Soil Profiles in the Lake Vinderel Area, Maramureş, Romania

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The Maramureş Mountains are the highest mountain massif located on the northern border of Romania with Ukraine. In 2005, the Maramureş Mountains were declared a protected area under IUCN (The World Conservation Union) category V (Protected Landscape: Protected area managed mainly for landscape conservation and recreation). The main conditions for this designation were: a specific mountain landscape covered with forests alternating with alpine meadows, the presence of flora and fauna characteristic of the Carpathians, within ecosystems that are still stable (forests, pastures, river bodies, lakes and marshes, underground water), the existence of natural biotopes on a large scale and the preservation of the traditional way of life (Phillips 2002, Năstase et al. 2010).

The research area is located in the Inner Eastern Carpathians, which are part of the Dacia megaunit. Lake Vinderel is in the Black flysch unit, which belongs to the Outer Dacids as the innermost cover of the flysch zone of the Eastern Carpathians (Gröger et al. 2013; Ianovica et al. 1968). The study of soil samples from the vicinity of Lake Vinderel is carried out as accompanying research of the lake itself. Soil, lake samples and surrounding rocks were sampled in June 2023. Lake Vinderel is located at an altitude of 1680 m above sea level (ASL). The first soil profile (V2; 120 cm, 5 samples) was sampled directly at the edge of the lake in a landslide on the border of a grassy meadow and a part with almost no vegetation. The soil was developed on a gray sandy clay similar to that sampled from the lake sediments. Fragments (up to 5 cm) of sandy phyllite were found in the area and within the profile. The second soil excavation was made on the grassy place of the Farcău peak (1957 m ASL). Stony soil with depth 40 cm (V4, 3 samples) was located on partially weathered but solid basalt. In most studied samples, the fraction below 63 μm (47-71 wt.%) dominates. Except for sample V4B, where the main fraction is above 2 mm. The pH increases with the depth of sampling. A strongly acidic environment prevails. Chemical and mineral analysis of soil and surrounding rock samples did not show any significant differences. The main clay mineral phases are illite and chlorite throughout the studied profile V2. To identify the possible presence of pedogenic clay minerals fine clay fraction less than 0.2 μm was prepared.

The results show that these are typical mountain soils with the initial stage of pedogenesis, belonging to the group of Leptosols. The soil developed on the basalt (Farcău peak) can be classified as Skeletic Leptosol. Probably also the soil profile at Lake Vinderel, but there it is not possible to talk about the predominance of the skeleton because the soil is on sandy clay, which also formed a larger part of the profile. A subtle but clear increase of $\delta^{13}C$ values with depth in the studied soil profiles is related to longer exposure to bacteria that reduce the lighter carbon isotope.

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The origin of quartz grains of the end-Triassic aeolianites from the Fatra Formation in the Tatra Mts (Fatric Unit, Western Carpathians, Slovakia) determined by cathodoluminescence microscopy

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Shallow-marine carbonate sediments of the Fatra Formation represent record of Upper Triassic transgression in the Zliechov Basin in the Central Western Carpathians. The base of the formation, recording progress of the transgression over terrigenous Carpathian Keuper deposits, is diachronous, so that the sequence starts with black shale, dolomitic limestone, or clastic limestone with sharp erosive base. The basal part of complete sequence of the Kardolína section (in the easternmost part of the Tatra Mts) consists of storm deposits (tempestites) followed by silty shales. Last mentioned lithology represents aeolianite products, characterising special conditions. We focused on these rocks containing valuable informations on palaeoclimate and on the geology of distant source area.

In accordance with the above, the main objective of our investigation is to find out source rock associations of quartz particles of the studied aeolianites using the cathodoluminescence (CL) microscopy. The CL examination displays a predominance of quartz grains of regional metamorphic as well as plutonic provenance. Moreover, this examination shows that the studied rocks include a minor quartz particle population with eventual pegmatitic and hydrothermal provenances. Apparently, this larger quartz particle variance mirrors a vast source area supplying material for the sedimentary basin. Thus, we do not suppose that this area could be small and simultaneously diversified in types of rocks. Quartz particles having relict cement rims suggest that they are minimally second cycle and they presumably conduce to the larger variance in the parent rocks. Furthermore, the CL examination exhibits that quartz grains with red luminescence (such grains could have a volcanic provenance) are absent. To summarise, the studied sediments were likely sedimented in a passive margin setting and fed by sources from the ancient interior of the continent (most likely from the Bohemian Massif).

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Comparison of the changes in the foraminiferal assemblages at the Badenian (Konkian) - Sarmatian boundary in the Central and Eastern Paratethys

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The Sarmatian Basin simultaneously replaced both the Badenian in the Central Paratethys and the Konkian in the Eastern Paratethys, and its base is 12.65 Ma (e.g., Ter Borgh et al. 2014, Palcu et al. 2015, 2017).

In the Central Paratethys, the Badenian-Sarmatian (s.str.) boundary was characterized by a significant biota change (e.g., Harzhauser & Piller 2004, 2007, Ter Borgh et al. 2014) designated as the Baden-Samanian Extinction Event (BSEE) (Harzhauser and Piller, 2007). Sharp alterations were also observed in the foraminifera species composition and the paleoecological characteristics of their assemblages. The late Badenian benthic foraminiferal assemblages in different areas of the Central Paratethys comprise normal-marine stenohaline species (*Bolivina-Bulimina* zone, *Hanzawaia crassiseptata* zone), which are succeeded by Sarmatian (s.str.) associations characterized by the dominance of euryhaline species (*Anomalinoides dividens* zone, *Elphidium angulatum* zone) (e.g., Harzhauser & Piller 2004; Nováková et al. 2020, Peryt et al. 2024).

In the Eastern Paratethys, the Konkian-Sarmatian (s.l.) boundary is also characterised by changes in the biota. (e.g. Muratov & Nevesskaya 1986; Nevesskaya et al. 1986). However, the study of foraminifera in different areas of the Eastern Paratethys (Northern Peri-Black Sea Region, Kerch Peninsula, Ciscaucasia, Mangyshlak Peninsula) demonstrate that the first significant changes in the foraminiferal assemblages are observed not at the Konkian-Sarmatian (s.l.) boundary, but earlier in the late Konkian (e.g. Vernigorova 2008, 2018, Golovina et al. 2009, Bratishko et al. 2015). The late Konkian differs from the rest of the Konkian in that it comprises foraminifera assemblages with a sharply decreased number of species (the number of their tests is also small) and is dominated by euryhaline species. The species composition of foraminifera assemblage of the late Konkian has its peculiarities. The assemblages comprise typical Konkian species e.g. *Quinqueloculina guriana, Varidentella reussi sartaganica, Elphidium kudakoense, E. jukovi*), and the Early Sarmatian (s.l.) species can also be present (e.g. *Elphidium horridum, Porosononion martkobi, Nonion bogdanowiczi*) (e.g. Vernigorova, 2008, 2018, Golovina et al. 2009). The Konkian age of deposits with such foraminiferal assemblages is confirmed by the presence of the Konkian index species of molluscs, ostracods, and nannoplankton (e.g. Prisyazhnyuk et al. 2007, Vernigorova et al. 2006, Vernigorova 2008, Golovina et al. 2009). It is also noteworthy that a decrease in species diversity and alterations in paleoecological characteristics of mollusc assemblages were also identified already in the late Konkian (Muratov & Nevesskaya 1986).

The foraminifera species composition of the Early Sarmatian (s.l.) of the Eastern Paratethys differs from that of the late Konkian, comprising two coeval euryhaline assemblages. The first is a Nonionidae-Elphidiidae assemblage (Bogdanovich 1965), which is dominated by *Porosononion subgranosus, P. martkobi, Nonion bogdanowiczi, Elphidium horridum, E. macellum* and *E. reginum*. The second is a Miliolidae assemblage (Bogdanovich 1965), which is dominated by the following species: *Quinqueloculina reussi reussi, Q. consobrina nitens, Q. consobrina sarmatica, Q. collaris, Articulina sarmatica* and *A. problema*, among others.

Consequently, in contrast to the Central Paratethys, where a marked change was observed in the species composition and paleoenvironmental characteristics of foraminiferal assemblages at the Badenian-Sarmatian (s.str.) boundary, in the Eastern Paratethys a similar change was already noted in the late Konkian.

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Organic matter dynamics and paleoenvironmental changes in an epicontinental basin (Miocene of the northern Pannonian Basin): Insights from biomarkers, palynology, and geochemical proxies

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The accumulation of organic matter (OM) is controlled by a complex interplay of physicochemical factors (e.g., Demaison & Moore 1980; Zonneveld et al. 2010), making it difficult to identify a single determinant that fully explains OM accumulation in any specific sedimentary setting (Demaison & Moore, 1980, He et al. 2017). Factors such as paleoclimate, paleoproductivity, sedimentation rate, redox conditions, and paleosalinity all influence the deposition and preservation of OM (Demaison & Moore, 1980, Bohacs et al. 2000, Zonneveld et al. 2010). In particular, epicontinental seas and shallow, restricted basins are strongly influenced by fluctuations in sea level, local bathymetry, and potential restrictions (Robinson & Whiteside 2022). Epicontinental basins are particularly susceptible to significant paleogeographic changes, which directly impact the OM preserved in the depositional record.

This study examines the Middle to Late Miocene strata within the northern Pannonian Basin System through sedimentological, petrographic, and geochemical analyses of core samples from the Danube Basin.

The goal of this study was to explore the factors influencing the characteristics of OM. During the late Middle Miocene (~12.3 Ma), the Central Paratethys Sea maintained normal marine salinity, with dysoxic conditions in the deeper basin areas, which enhanced the accumulation of aquatic OM. The final phase of rifting occurred during the Late Miocene, resulting in the formation of the deep Lake Pannon. Similar to seawater, the brackish lake water still contained sulfate. The open lacustrine deposits from this period (~11.6–10.0 Ma) suggest that the OM originated from submerged or floating macrophytes and algae, while the presence of deciduous trees and shrubs along the shores indicates a humid climate.

The study identifies hybrid event beds (HEBs) on the floor of Lake Pannon (~10.0–9.3 Ma), where currents redistributed mud and OM, leading to similarities between the Middle Miocene and Late Miocene deposits. During turbidite deposition (~9.3–9.0 Ma) from the paleo-Danube, there was a shift in the OM composition, with terrestrial material replacing algae. Following the complete isolation of Lake Pannon from its main water masses (~9.0–8.9 Ma), the sources of OM shifted from algae to macrophytes, coinciding with a drop in salinity that was likely linked to a peak in humidity.

The subsequent deltaic phase (~8.9–8.6 Ma) is characterized by the development of well-formed topset lakes, swamps, and floodplain forests, indicative of warm temperate to subtropical climates. The Middle-Upper Miocene deposits analyzed in this study are identified as source rocks with fair to very good organic richness and poor to fair generative potential, primarily containing kerogen types III and IV, with type II being rare. The rapid paleoenvironmental shifts occurring over approximately 100 kyr led to a complete change in both the type and delivery of OM, highlighting the complexity inherent in epicontinental basins.

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Eo-Alpine collision and thrusting of the Veporic Unit onto Tatric Unit in the Nízke Tatry Mts. (Western Carpathians)

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The Western Carpathians are a part of the European Alpine orogenic belt, which continues to the Eastern Alps in the west and the Eastern Carpathians in the east. The mountains are divided into the External, Central, and Internal Western Carpathians (e.g., Andrusov et al. 1973, Plašienka 2018). The study area is in the western part of the Kráľovohoľské Tatry Mts. and covers the Veporic and Tatric tectonic units and coincides with the Čertovica shear zone. During the Eo-Alpine time, the Veporic Unit collided with the Tatric Unit and was thrust on it. The wide area along the Čertovica shear zone has an imbricated structure with several partial thrusts especially in the Veporic Unit in the hanging wall position. The main objective of this study was a detailed analysis of the deformation structures and their precise spatial orientation and pattern.

The Veporic crystalline basement is mainly composed of para- and orthogneisses, micaschists, and amphibolites, which were predominantly affected by high- to medium-grade Variscan metamorphism (M_{V2}) and then by a generally low-grade Alpine overprint (M_{A1}). The Variscan deformation (D_{V2}) is characterised by pervasive metamorphic foliation (S_{V2}) which is well-developed in the entire crystalline basement of the study. This Variscan fabric (S_{V2}) was a suitable marker for determining the Alpine deformation.

The Alpine deformation (D_{A1}) was accompanied by retrograde lower greenschist facies metamorphosis (M_{A1}). Therefore, the complete transposition of S_{V2} to the S_{A1} fabric originated only very locally, making it possible to study the relationships between the deformations. The evolution of Alpine tectonic fabric (S_{A1}) is more significantly localised to shear zones and evolved during the Cretaceous orogeny (Eo-Alpine deformation).

The spatial distribution of the measured Alpine mylonitic foliation and crenulation cleavage (S_{A1}), mineral and stretching lineations (L_{A1t}) shows the NNW–SSE shortening. The foliations (S_{A1}) have generally NE–SW striking and dip shallowly or moderately to the SE. The deformation (D_{A1}) is accompanied by crenulation lineation, fold axes, and intersection lineations (L_{A1c}) showing the NNW–SSE shortening. The folds (F_{A1}) are often asymmetric. From these observations, we can unambiguously determine that the shortening was carried out during the simple shear tectonic regime with top-to-the-NNW tectonic transport which determines the kinematics of the Alpine thrusting from 105 to 90 Ma.

The Alpine deformation (D_{A2}) is represented by the exhumation of the Veporic Unit, which most likely reflects underthrusting of the Tatric crust. The en-block exhumation of the already finished internal structure of the Veporic Unit established was carried out most probably between 80 and 55 Ma (Vojtko et al. 2016, Kriváňová et al. 2023, Vojtko & Kriváňová 2024).

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The fossil remains of fish (otoliths) from the Lower Badenian sediments from the Hrušovany nad Jevišovkou locality (Carpathian Foredeep, Czech Republic)

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The Carpathian Foredeep is a peripheral fore land basin developed on the European plate margin due to the Western Carpathian accretionary wedge overthrust and deep subsurface load. The sedimentary record started in the late Egerian/Eggenburgian and terminated by the early Badenian (Nehyba et al., 2008). Early Badenian deposits are generally poorly exposed in the Carpathian Foredeep, but nevertheless fish remains (bones, teeth and otoliths) are often found in them.

In 2003, the Slovak National Museum - Natural History Museum in Bratislava collections received material from the research of prof. RNDr. Jozef Švagrovský, DrSc. from the Department of Geology and Paleontology of the Comenius University in Bratislava. The material is gradually being recorded and during the processing of several sediment residues from the locality Hrušovany nad Jevišovkou various species of foraminifers, ostracods, corals, echinoderms, bivalves, gastropods, crabs and described remains of fish fauna - otoliths have been isolated from the sediment.

Prof. Švagrovský studied mainly molluscs from this locality, but his summary article was not published. Brzobohatý (1995) mentions the otolith from the locality of Hrušovany nad Jevišovkou in his summary of the Macrurids. In another paper, Brzobohatý (1997) presents 17 taxon of bony fish and expressed the opinion that, based on the composition of the fish fauna community he described, the mesopelagic (family Myctophidae) and archibenthic (family Macrouridae) association of the fish community is dominant. The depth of sedimentation is higher than 400 m. Zahradníková (2010) in her conference paper describes 5 fish species based on the study of otoliths. In the last known work by Brzobohatý & Nolf (2018), they report 36 taxa of fossil fishes in their paper on otoliths from the Carpathian foreland from the locality Hrušovany nad Jevišovkou. In this paper, new material is also treated, otoliths that were obtained by separation under a binocular microscope from raw sediment residues in 2023 and which are deposited in the Paleontological Department of the SNM-NHM in Bratislava. These are 28 pieces of the sagittal otoliths.

The city of Hrušovany nad Jevišovkou is located 26 km East of Znojmo and 5 km from the border with Austria on the Jevišovka River. From a broader geological point of view, it is a territory located in the Dyje vault. The Miocene sediments of the Carpathian foothills were deposited on the bedrock in repeated transgressions. Probably the oldest sediments are the sediments of the Eggenburgian-Ottnangian Formation. The Karpatian sediments have the greatest distribution and are in two facies phases. The Badenian sediments are bounded by a tectonic line in the W, while in the NW, E and S they smoothly continue into the adjacent areas. They come to the surface in a strip in the W-E direction between the villages of Novosedly, Hrušovany and Litobratčice. The maximum thickness of the sediments of the Lower Badenian is assumed to be up to 300 m. They are represented by strongly calcareous grey, grey-brown and green-grey silty clays and loams and yellow-brown to yellow fine-grained sands with a grey tinge. The clays are characterised by weak lamination. The sands of the Lower Badenian are usually well sorted (Studený 2014).

The remains of fossil fish were found in five sediment residues - bags. For better orientation, they were numbered from 1 to 5. The bags were labelled with the following site descriptions: Hrušovany nad Jevišovkou, southern edge near the old brickyard (HR1); Hrušovany nad Jevišovkou, clay of the brickyard, upper position (HR2); Hrušovany nad Jevišovkou, clay of the brickyard, upper position (HR3); Hrušovany nad Jevišovkou, railway crossing (HR4) and Hrušovany nad Jevišovkou, road cut by the railway (HR5).

Otoliths belonging to the family Myctophidae Gill, 1893 were the most numerous. Species belonging to the genus *Diaphus* Eigenmann & Eigenmann, 1890 namely *Diaphus acutirostrum* (Holec, 1975), *Diaphus austriacus* (Koken, 1891), *Diaphus cahuzaci* Steurbaut, 1979, *Diaphus haereticus* (Brzobohatý & Schultz, 1978), *Diaphus obliquus* (Weiler, 1943), *Diaphus regani* Taaning, 1932 and *Diaphus taaningi* Norman, 1930 were determined. The species *Hygophum derthonensis* Anfossi & Mosna, 1969 was determined from the genus *Hygophum* Bolin, 1939. One otolith found belongs to the genus *Lampadena* Goode & Bean, 1893 of the species *Lampadena speculigeroides* Brzobohatý & Nolf, 1996 and one to the genus *Symbolophorus* Bolin & Wisner, 1959 of the species *Symbolophorus weileri* (Brzobohatý, 1965). A single otolith belongs to another family namely to the family Melanonidae Marshall & Cohen, 1973, to the genus *Melanonus* Günther, 1878 namely the species *Melanonus triangulus* (Robba, 1970).

The described fish assemblage consisting mainly of species belonging to the family Myctophidae Gill, 1893 indicates deeper sedimentation conditions. The representatives of the family Myctophidae represent the most abundant distributed component of the fish mesopelagic in today's seas and oceans. Their representatives have a wide bathymetric range. They most commonly inhabit depths between 200 and 1000 m. Most species of this family migrate and ascend almost to the surface at night. Representatives of the genus *Melanonus* Günther, 1878 of the species *Melanonus triangulus* (Robba, 1970) represent fish living also in deeper mesopelagic waters (200-1000 m) in the tropical, temperate, but also in the subantarctic climates.

According to the determined community of fish fauna from the Hrušovany nad Jevišovkou site, we can confirm that the Lower Badenian clay sediments in which the described otoliths were found were deposited in a basin more than 200 m deep.

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