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XXIXth Meeting of the Petrology Group of the Mineralogical Society of Poland

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In Memoriam: Prof. dr hab. Jan Burchart (1932–2024)

It is with great sorrow that we reflect on the passing of Professor Jan Burchart, a towering figure in the field of geological sciences, who left an indelible mark on the study of petrology, isotopic geochemistry, and geochronology. A corresponding member of the Polish Academy of Sciences from 1991, he dedicated nearly five decades of his life (1956–2002) to the Institute of Geological Sciences, serving as head of the Geochronology Department from 1991.

As the founder of the modern isotope geochemistry laboratory at the Institute of Geological Sciences, Prof. Burchart was a pioneer in his field. His work laid the foundation for studies that employed isotope methods to determine the age and origin of rocks, introducing techniques such as the Rb-Sr and Sm-Nd methods for dating rocks. In the 1970s, he spearheaded research that led to the development of a method for reconstructing the thermal history of minerals, making lasting contributions to geochronology. Professor Burchart will probably be best remembered for his achievements in fission track thermochronology as a pioneer of this method not only in Poland but also in the world. His early work on the crystalline rocks of the Tatra Mountains remains seminal. He was one of the few researchers from behind the Iron Curtain who, since the late 1960s, published in the most prestigious world journals such as American Journal of Science (1968), Earth and Planetary Science Letters (1972, 1983) and Nuclear Tracks (1981).

Beyond his laboratory achievements, Prof. Burchart was a gifted educator and mentor, teaching at renowned institutions including the University of Philadelphia, the University of Silesia, and the University of Warsaw. His influence on the next generation of geologists cannot be understated, as he guided young scientists with his deep expertise and passion for discovery. He was the supervisor of two PhD theses prepared by Grzegorz Zieliński and Robert Bachliński, who are still active in

Earth sciences. His textbook, “An Isotopic Record of Earth's Past” (2015), co-authored with Ján KráĺKráĺ, became a seminal resource for students and specialists alike, helping to disseminate complex geochronological methods to a broad audience.

In addition to his teaching and research, Prof. Burchart's leadership extended to numerous scientific committees and councils, where he shaped the direction of geological research in Poland. He was a member of Division VII (Earth and Mining Sciences) and Division III (Exact Sciences and Earth Sciences) at the Polish Academy of Sciences, and actively served in the Committee of Mineralogical Sciences and the Committee of Geological Sciences. He served as Deputy Chairman of Division VII from 1990-1998. Professor Jan Burchart was a member of the scientific councils of the Institute of Geological Sciences and the Institute of Geophysics (1995-2007). He belonged to the Warsaw Scientific Society and from 2007 was a member of the Ethics in Science Committee of the Polish Academy of Sciences.

Renowned for his expertise in the petrology of igneous and metamorphic rocks, isotope geology and geochronology, Prof. Burchart's career was filled with numerous accolades. He was awarded high state distinctions such as the Gold Cross of Merit and the Knight's Cross of the Order of Polonia Restituta, along with prestigious domestic and international awards, honouring his prolific contributions to science. He forged collaborative ties with many foreign research institutions, where his research helped revolutionize the study of the Earth’s history through isotopic analysis.

As we say goodbye to this distinguished scholar, we celebrate not only his profound contributions to geosciences but also his legacy as a teacher, mentor, and innovator. He is remembered not only for his remarkable scientific achievements, but for his dedication to advancing knowledge, fostering collaborations, and inspiring countless students and colleagues. His legacy lives on in the enduring impact of his work and the many geologists who continue to benefit from his ground-breaking research. The funeral ceremony took place on January 31, 2024 at the Evangelical-Augsburg Church of the Holy Trinity in Warsaw. Professor Burchart is buried at the Evangelical-Augsburg Cemetery in Warsaw.

Stanisław Mazur

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Dating the Undatable: Geochronology of fluid-rock interaction processes and implications for volatile cycling in subduction zones

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Fluid release under high-pressure conditions during subduction is largely demonstrated by the occurrence of eclogite-facies metamorphic veins and metasomatic rocks in the serpentinized mantle and in the overlying crust. Time constraints on serpentinite dehydration are crucial if we are to better understand the *P-T-t* evolution of serpentinites, the mechanism of fluid flow, and the fate of volatile elements at depth. However, dating (de)hydration reactions and associated deformation in ultramafic rocks such as serpentinite is notoriously difficult due to the scarcity of suitable minerals for geochronology. In addition, the suitable minerals such as titanite and perovskite often have very low U — and thus low radiogenic Pb concentrations — while containing a variable amount of initial common-Pb.

We have studied different types of metamorphic and metasomatic rocks associated with subducted serpentinites in three metaophiolitic units in the Western and Central Alps: metarodingites and ophicarbonates from the Zermatt-Saas unit (Western Alps), ophicarbonates from the Lanzo Massif (Western Alps), and carbonate veins from the Val Malenco unit (Central Alps). Petrological, geochemical and geochronological data are presented and their implications for fluid flow and volatile cycling processes in subduction zones are discussed.

Serpentinite-hosted carbonate rocks (i.e., ophicarbonates) play an important role in the deep C cycle because they can occur both in the slab and in the mantle wedge. A large body of work has challenged the paradigm of carbonate stability during subduction at the forearc and subarc (> 80 km) conditions, revealing a variety of complex processes that play an important role in the so-called slow C cycle. Understanding if, when and how ophicarbonates devolatilize is therefore a fundamental piece of the deep C cycle puzzle. We addressed these questions in two case studies. i) The ophicarbonates from the Zermatt-Saas unit — subducted up to eclogite facies conditions at 2.5 GPa, 560° C overlie a large body of partially dehydrated serpentinites. Our petrological and geochemical investigation, as well as thermodynamic modelling, reveal that the metamorphic evolution of these rocks was in a closed system, where calcite/aragonite was replaced by metamorphic dolomite and diopside. This reaction is nearly CO_2 conservative, with the composition of the released fluid close to pure water at redox conditions below the fayalite-magnetite-quartz buffer (Piccoli et al., in review). ii) Ophicarbonates from the Lanzo Massif were instead infiltrated by reduced fluids, which triggered devolatilization and deformation. In situ dating of perovskite crystals in shear bands returned a peak age of 49.6 ±1.0 Ma, corresponding to the age of the regional high pressure metamorphism (Piccoli et al., 2022). Moreover, perovskite in shear bands contains CH_4 fluid inclusions, indicating that abiotic methane formation occurred at depth of ca. 80-90 km. The production of reduced fluids at depth has also important geo-biological implications because deeply sourced carbonic fluids may feed the subsurface microbial life at convergent margins (Barry et al., 2019; Vitale Brovarone et al., 2020).

The occurrence of carbonate veins from the Val Malenco unit (Central Alps) also indicates that devolatilization is associated with a major deformation event. We investigated perovskite-bearing carbonate veins from the NE ridge of the Sasso Moro. The Ca-carbonate veins are partially rotated and parallelized to the foliation, but discordant veins are also observed. Perovskite from these veins yield a U-Pb age of 48.9 ±0.5 Ma, which is interpreted as a mineral growth age (Piccoli et al., 2022). In the context of previous geochronology, this age clearly postdates the formation of the nappe stack responsible for thrusting the Margna-Sella nappes over the Malenco unit. We suggest that perovskite crystallized in the veins during deformation related to a second main thrusting event, recorded by the top-to-the-south pervasive shear foliation, which is clearly separated in age from the initial nappe stacking. We conclude that during this second compression event, partial dehydration of the serpentinites favored C, Ca and Ti mobility, resulting in the formation of carbonate-perovskite veins.

In the case of the Lanzo Massif ophicarbonates and Val Malenco carbonate veins, the dated accessory mineral perovskite was clearly associated with fluid escape structure and microstructures. However, in many cases it is difficult to establish petrogenetic relationships between major minerals — on which P-T estimates are based — and accessory minerals — on which geochronology is based. This has been a significant shortcoming for petrochronological studies. A recent advance is the ability to perform in situ U-Pb analysis of garnet by laser ablation-inductively coupled plasma-mass spectrometry (LA-ICPMS) (Millonig et al., 2020). Andradite- and grossular-rich garnet is common in metarodingites and this garnet composition is particularly amenable to U-Pb geochronology, making garnet U-Pb geochronology in metarodingites a potentially new robust tool for providing chronological constraints on evolution of ultramafic units (Piccoli et al., 2024). In fact, metarodingitets are particularly interesting because they undergo the same *P-T-t* history as the surrounding serpentinites. Furthermore, metarodingites and associated blackwalls often show zoned minerals and vein networks, indicating multiple (de)hydration events. Their petrochronological investigation can therefore provide information on the timing of (de)hydration and fluid composition variation during subduction. We have investigated the chemical and chronological record of garnet, titanite, and zircon from metarodingites and garnet veins in chloritized blackwalls, from the Zermatt-Saas unit (Western Alps). Garnet in the chlorite-rich metasomatic rind (blackwall) displays re-crystallization and new growth textures and therefore represents a second generation of garnet (Grt2), postdating garnet formation in the metarodingite core (Grt1). 2D major and trace element maps show that Grt1 preserves chemical zonation with decreasing HREE patterns from core to rim, consistent with fractional garnet growth. LA-ICPMS U-Pb dating of metarodingite garnet Grt1 samples yielded overlapping ages between 43.6 ±0.9 and 44.1 ±1.3 Ma — consistent with previous estimates of peak metamorphic conditions. Trace element mapping of Grt2 shows that the second generation of garnet is Ti-Fe^{3+} rich and has no decreasing HREE patterns from core to rim. This indicates that, during exhumation, Ti, Fe^{3+}, and REE were partially mobile in fluids and that REE supply was not transport limited. U-Pb ages of two blackwall garnet samples (Grt2) are significantly younger, yielding ages of 40.1 ±0.9 Ma and 38.4 ±0.8 Ma, respectively. The presence of multiple generations of metasomatic garnet in the blackwall suggests that periods of increased rock permeability occurred repeatedly aided by deformation. Importantly, titanite and zircon U-Pb ages yield consistent results showing that U-Pb dating of grossular-andradite garnet from eclogite-facies rocks is a robust geochronometer.

Acknowledgments: This abstract summarize the work conducted with great collaborators, without whose contributions it would have not been possible. F.P. is grateful to Leo Millonig, Maria Ovtcharova, Marcel Guillong, Axel Gerdes and Aaron Hutter for analytical help and insightful discussions.

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Western Carpathians and Eastern Alps – connections and disconnections

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The Western Carpathians (WeCa) and the Eastern Alps (EA) are adjacent parts of the same Alpidic orogenic belt of Central Europe. As such, they share many common aspects in their structure, composition and tectonic evolution. The present, substantially dissimilar appearance of both mountain ranges is the ultimate result of their markedly different post-Eocene evolution. While the severe head-on collision took place in the EA, which strongly modified the pre-collisional structures, an eastward extrusion/escape affected the WeCa segment of the AlCaPa (Alpine–Carpathian–Pannonian) Megaunit east of the Tauern Window. This ensued in lithospheric thinning, development of large extensional basins and widespread volcanism. Unlike in the EA, the pre-Oligocene structural pattern is therefore well preserved in the WeCa. As a result, both mountain ranges exhibit a dissimilar structural pattern of essentially the same pre-Oligocene tectonic units, mainly due to a very different late Alpine uplift/exhumation histories and erosional level. Some phenomena are well exposed and long-term studied in the EA, but supressed in the WeCa, and vice-versa. It means that combination of data from both orogenic belts provide a complementary geological record, which should be reflected in regional correlations and evolutionary tectonic models.

The aim of this contribution is to correlate major tectonic units of the WeCa and EA based on their structure and composition, and to characterize their pre-Oligocene evolution starting from the Mesozoic pre-orogenic rifting processes up to the gradual growth of the orogenic wedge. This overview is compiled from various sources that are referred to in synthetic papers by Plašienka (2018; Plašienka et al., 2019, 2020).

There are two major tectonic systems in the structure of the EA and WeCa – the structurally lower Pennine (or Penninic) and superimposing Austroalpine. In the southern WeCa zones, still higher Tethyan tectonic system is distinguished, which also has some analogues in the EA. The Penninic, ophiolite-bearing units represent the subduction-accretion complexes formed during suturing of two branches of the Penninic Ocean (a.k.a. Alpine Tethys resp. Alpine Atlantic). These two oceanic zones and an intervening continental fragment gave rise to three nappe groups.

The **Lower Penninic units** were derived from the Valais–Rhenodanubian–Magura oceanic domain, which opened during the Early Cretaceous and closed in the Late Eocene, include two types of units. The Rhenodanubian–Magura fold-thrust system creates the inner zone of the accretionary Flysch Belt overriding the Helvetic units in the Alps and Silesian–Krosno units in the Carpathians. It is composed of Cretaceous–Eocene sedimentary formations scraped off the Valais–Magura Ocean lithosphere and accreted to the orogenic front from the Late Eocene in the west to the Oligocene in the east. The former age concerns the

Rhenodanubian Flysch Belt of the EA and the inner-westernmost Biele Karpaty Unit of the Carpathian Magura Belt, while the latter applies for the rest of the Magura Nappe proper (Krynica, Bystrica, Rača and Siary units). The metamorphic Central Alpine Lower Penninic units are restricted to the EA tectonic windows emerging from below the Upper Penninic elements and Austroalpine thick-skinned thrust stack. The Glockner nappe system in the Tauern Window includes various, probably Cretaceous deep-marine metasediments and metaophiolites. The lower unit of the Rechnitz–Kőszeg group of tectonic window at the eastern extremity of the EA includes similar metamorphic complexes.

The **Middle Penninic units** representing the continental Briançonnais Ridge that separated both oceanic branches are only distinguished in the Western Alps. In the EA east of the Penninic Engadine window, the differentiation between the two oceans is meaningless, since the Briançonnais domain wedges out and both oceanic branches merge into one Penninic oceanic tract formed by two rifting-spreading cycles.

However, the **Pieniny Klippen Belt** (PKB, its Oravic units) is generally regarded as the structural element in the Middle Penninic position. The character of the Oravic sedimentary successions points to their derivation from a continental basement, presumably a narrow dissected intra-oceanic ribbon known as the Czorsztyn Ridge positioned between two branches of Alpine Atlantic.

The **Upper Penninic units** represent the southern, Ligurian–Piemont oceanic branch that opened during the Middle Jurassic, partially closed by the end of Cretaceous and fully subducted in the Eocene. They are exposed in the Eastern Alpine tectonic windows (Engadin, Tauern, Rechnitz) and involve ophiolitic and exhumed continental mantle mafic-ultramafic, ocean-floor magmatic rock association overlain by the Middle–Upper Jurassic radiolarites and maiolica-type limestones, Cretaceous Bündnerschiefer, olistostromes and flysch sediments. The mélanges of the Matrei Zone rimming the Tauern Window contains also blocks derived from the overriding Austroalpine basement and cover complexes. The Upper Rechnitz Unit is composed of ophiolitic basalts and serpentinites and Jurassic–Cretaceous metasediments. Lenses of blueschist-facies metabasalts record the Late Paleocene subduction-related high-pressure (HP) metamorphic event.

Extension of the Upper Penninic units and their parental Ligurian–Piemont Ocean into the Western Carpathian area is challenging. It was inferred that this could be represented by the Belice Unit which was assigned to a higher-order superunit Vahicum as an equivalent of the Alpine Upper Penninic units, and the corresponding oceanic realm was named the Váh Ocean. Although strongly imbricated and dismembered, the Belice sedimentary succession is nearly identical with the standard lithostratigraphy of the Upper Penninic units, namely their uppermost Platta and Tsaté nappes, and Arosa and Matrei mélange zones. Inferred structural and partly also compositional analogues of the Piemont–Vahic oceanic units occur at the junction area of the Western and Eastern Carpathians with the Pannonian domain (Iňačovce–Krichevo–Szolnok–Sava Zone).

The **Austroalpine tectonic system** (AA) builds up the largest interior part of the Eastern Alpine – Western Carpathian orogen. In general, the AA system represents a huge stack of Cretaceous basement/cover nappes that were progressively accreted to the northward-propagating Alpine–Carpathian orogenic wedge which nucleated along the Upper Jurassic Meliata suture and progressed to the Upper Cretaceous South Penninic suture. The AA system includes a range of large-scale tectonic superunits and numerous local subunits embracing both basement-involved thrust sheets and purely décollement sedimentary cover nappes. Thrust stacking was accompanied by various degree of deformation from ductile to brittle, and metamorphic recrystallization from very low-grade or unmetamorphosed to locally eclogite-facies. The Cretaceous pressure and temperature transformations of AA units are defined as the Eo-Alpine (or Palaeo-Alpine) metamorphism.

The **Lower Austroalpine units** (LAA) relate to the rifted Adriatic continental margin facing the Penninic Ligurian–Piemont Ocean to the north. They form the weakly (WeCa) to moderately (EA) deformed and metamorphosed thrust sheets or basement-cored fold nappes. As a result of their passive and then the active margin position, the composition and structure of LAA units were affected by Jurassic rifting and Cretaceous shortening during closing of this oceanic domain and ensuing collision of its margins. Consequently, the post-Variscan sedimentary cover is often reduced or missing in the EA, but nearly complete Mesozoic cover successions are present in the westernmost LAA units in the Swiss Central Alps, as well as in the WeCa areas.

The **Tatricum** is one of the most characteristic superunits of the Western Carpathians. It is a large-scale, thick-skinned thrust sheet overriding the presumed Penninic Piemont–Vahic oceanic suture. However, only the frontal Tatric elements – the **Infra-Tatric units** (such as the Borinka, Inovec and Kozol units) occupy an analogous structural position and exhibit comparable rifting to stacking evolution like the LAA units. The main Tatric body, although generally correlated with the LAA system, has no direct counterpart in the EA from both the compositional and structural aspects. First of all, and unlike the LAA, the exposed parts of the Tatric complexes are little affected by the Alpine tectono-metamorphic transformations. Secondly, the Tatricum as a whole is an upper-crustal, about 10–15 km thick and 50 km wide basement slab overridden by thin blankets (3–5 km) of the Fatric and Hronic cover nappes. No such large continuous basement sheet with almost untouched sedimentary cover occurs in the Central EA.

In the EA, units of the **Upper Austroalpine** (UAA) tectonic system are exposed in two large, fairly independent areas. The Northern Calcareous Alps is a wide belt of detached cover nappe systems, partially separated by Cenozoic strike-slip fault zones from the Central Eastern Alps to the south. The latter are basically built by a thick pile of basement/cover nappes, most of which were affected by various degree of the Eo-Alpine metamorphism.

The **Northern Calcareous Alps** (NCA) embrace three groups of décollement cover nappes – the Bajuvaric, Tirolic–Noric and Juvavic systems from bottom to top. All are composed of variable Permian to Cretaceous sedimentary successions deposited in continental, shelf, slope to deep-marine environs. In general, the Bajuvaric nappes correspond by the position and Jurassic–Cretaceous lithostratigraphy to the Fatric nappe group of the WeCa, the Tirolic cover units are in part correlative to the Hronic nappes, the Noric basement sheets comparable to some Gemeric complexes, and the Juvavic elements that are analogous by the uppermost structural position, but not by composition, to the WeCa Silicic nappes. The nappe stacking was completed in mid-Cretaceous times and nappe contacts were then unconformably overlain by variable Turonian–Eocene sediments of the **Gosau Group**. However, the final emplacement of the NCA thrust stack took place as late as during the Oligocene collision of the Alpine thrust edifice with the European plate. Consequently, the NCA units were affected by out-of-sequence thrusting, including the Gosau deposits trapped in several imbricated synforms. In contrast to the WeCa, the whole NCA stack and the frontally accreted Rhenodanubian flysch units overrode southern European margin (Bohemian Massif) and autochthonous parts of the foreland Molasse Basin for a distance of about 50 km.

The NCA nappe systems continue NE-ward into the Central WeCa via the Vienna Basin subcrop. However, their composition and structure is changing to some degree, since the Carpathian cover nappes largely preserve their original Cretaceous structure and were little influenced by the post-nappe deformation. Nevertheless, a quite narrow zone that follows the southern boundary of the PKB, the so-called Peri-Klippen Zone, appears to be a reduced analogue of NCA.

In the **Central Eastern Alps**, the UAA thrust system is subdivided into the Lower Central and Upper Central Austroalpine units (LCAA and UCAA, respectively). The **Lower Central Austroalpine** units (formerly designated as the Middle Austroalpine) are composed of the high-grade Variscan basement overlain by Permian–Mesozoic cover sediments in places. The basement complexes experienced southwards increasing Eo-Alpine metamorphic overprint from the greenschist up to eclogite facies. The **Upper Central Austroalpine** nappe system forms the uppermost group of basement-involved nappes with combined Variscan and Alpine thrust contacts, which are in part structurally connected with the Tirolic cover nappes of NCA.

South-east of the Tatric area, the Central WeCa zones comprise two basement/cover thrust sheets (Veporic and Gemeric) that are partially correlative to the LCAA and UCAA elements of the EA. The **Veporicum** is a crustal-scale basement wedge which has many characteristics, but also differences, compared to the large part of the LCAA basement units. The southern Veporic zones were affected by the Eo-Alpine metamorphism of the greenschist to amphibolite facies and associated deformation due to burial below the Gemeric sheet.

The Late Cretaceous to earlies Paleogene exhumation of the South Veporic metamorphic dome was achieved by the orogen-parallel extension and structural unroofing of the overlying Gemeric and higher units along the flatly east-dipping low-angle detachment faults. This scenario is comparable to certain LCAA metamorphic complexes, for instance the Gleinalm dome. Supposedly, the Veporic superunit corresponds to several LCAA complexes, which were more disturbed and additionally modified by Miocene extensional shearing in the EA, however.

The **Gemericum** is composed of the Lower Paleozoic volcano-sedimentary complexes altered by nearly isofacial Variscan and Eo-Alpine greenschist-facies metamorphism. Certain Gemeric units were directly correlated with the UCAA, e.g. the Ochtiná and Veitsch units. Gemeric units are overthrust by remnants of a structurally complicated blueschist- and ophiolite-bearing accretionary complex collectively defined as the **Meliaticum**. It is supposed to represent suture remnants of a Neotethyan branch – the Meliata Ocean. Possible analogues of the Meliata-type mélange occur in the eastern part of the NCA. The Florianikogel Unit occurs in an uppermost structural position in the NCA nappe edifice, which setting is fairly different from the WeCa.

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Granitic pegmatites of Western Carpathians: state of the art

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Introduction

Granitic pegmatites belong to characteristic and relative widespread rocks of pre-Alpine, Paleozoic crystalline basement of the Western Carpathians. Their principal occurrences relate to mid-Variscan (Mississippian, Carboniferous), orogen-related granitic rocks of S- to I-type affinity in the Tatric and Veporic Superunits. However, granitic pegmatites were rarely identified also in metamorphic rocks of the Gemeric and Zemplinic Superunits. The pegmatites represent the most fractionated members of granitic magmatism with signs of rare-element Be, Nb-Ta, (Li) mineralization.

Geological setting and zoning

The West-Carpathian granitic pegmatites form dykes, rarely lenticular bodies, intruded into Variscan granitic rocks (granites, granodiorites, tonalites, rarely diorites), less frequently also into Paleozoic (Ordovician to Devonian) metamorphic rocks of the amphibolite facies (paragneisses and micaschists, locally also orthogneisses, amphibolites and skarns). Thickness of the pegmatites reaches up to 1 m and their length achieves several to tens meters in usual cases, however some bodies attain thickness of 8 m and length at least 100 m (Moravany and Váhom pegmatite, Považský Inovec Mts.). The most widespread pegmatite occurrences are connected with peraluminous, muscovite-biotite (commonly almandine-bearing) leucocratic granites to granodiorites of dominant S-type affinity, such as the Bratislava Massif of the Malé Karpaty Mts., Bojná Massif of the Považský Inovec Mts., Suchý and Malá Magura Massif (Strážovské Mts.), and Žiar Massif. However, granitic pegmatites are relatively widespread also in some biotite granites to tonalites with dominant I-type affinity (especially in Prašivá part of the Nízke Tatry Mts. and in the Vysoké Tatry Mts.). Generally, the West-Carpathian granitic pegmatites show close spatial and genetic relationships to the Variscan granites, they are intragranitic or they occur in metamorphic rocks near contact with the granites.

The pegmatites commonly reveal textural and mineral zoning. The following zones could be recognized in the West-Carpathian pegmatites: (1) aplitic, (2) coarse-crystalline quartz–K-feldspar–muscovite–(biotite), (3) graphic K-feldspar–quartz, (4) blocky K-feldspar, (5) blocky quartz core, (6) saccharoidal to platy albite (cleavelandite), and (7) fan-shaped muscovite. The zones (1) to (5) are primary magmatic, whereas zones (6) and (7) are younger, late- to early post-magmatic and they metasomatically replaced the primary pegmatite zones. The size of minerals varies between 0.01 mm (saccharoidal albite) to ca. 10–50 cm (blocky and coarse-crystalline zones). Miarolitic cavities with well-developed euhedral crystals are missing in the West-Carpathian pegmatites.

Accessory and rare-element minerals

Vast majority of the West-Carpathian granitic pegmatites represent relatively primitive, barren pegmatites without presence of rare-element minerals. Almadine to spessartine, Hf-rich zircon (up to 22 wt.% HfO_2), fluorapatite, monazite-(Ce), pyrite, less frequently molybdenite, gahnite, uraninite, xenotime-(Y), cheralite, and native bismuth belong to characteristic accessory minerals of the pegmatites. However, the most fractionated West-Carpathian granitic pegmatites contain also accessory minerals of rare lithophile elements (Be, Nb, Ta, rarely B and Li). These pegmatites are located in the Tatric Superunit (Bratislava, Bojná, Suchý, and Žiar massifs, Nízke and Vysoké Tatry Mts.) and they contain primary magmatic beryl (columnar crystals up to ca. 20 cm; Uher et al., 2010), and Nb-Ta-(Ti-Sn) oxide minerals, mostly columbite-(Fe) to tantalite-(Mn), less frequently tapiolite-(Fe), ferrowodginite, ferrotitanowodginite, Nb-Ta rutile, and Ti-rich Nb-dominant ixiolite (e.g., Uher et al., 2007; Chudík et al., 2011). Moreover, Li-rich schorl to (fluor)elbaite with beryl, columbite-(Mn) and cassiterite were identified in newly discovered the Dobšiná pegmatites, possibly related to Permian Sn-W-Li granites (Gemeric Superunit).

Dating of pegmatites

Geological setting, petrography, geochemistry, and mineral composition data clearly indicated genetic link between the Tatric and Veporic West-Carpathian granitic pegmatites and their parental granitic rocks. Numerous recent in-situ U–Pb zircon and monazite dating document ca. 360 to 340 Ma age interval for emplacement of mid-Variscan, orogen-related granitic rocks (e.g., Kohút & Larionov, 2021). Recent results of the pegmatite minerals dating matches perfectly of granite ages. The in-situ U–Pb isotope dating of columbite-tantalite from three Tatric pegmatites gave pegmatite primary crystallization age of 360 ±5 to 352 ±8.5 Ma (Uher et al., 2024). Similar results also show U–Th–Pb monazite chemical dating (Uher et al., 2014) or Re–Os dating of molybdenite (Gawęda et al., 2013; Kohút & Larionov, 2021). On the other hand, preliminary results of uraninite chemical dating indicates also post-Variscan age interval of ca. 250 to 320 Ma (Nízke Tatry Mts.), probably connected with their hydrothermal overprint (Uher, unpublished data).

Evolution of pegmatites

Textural relationships and mineral composition indicate at least two principal evolutional stages of the West-Carpathian pegmatites: (1) Variscan primary magmatic stage, and (2) Variscan and/or Alpine secondary subsolidus (hydrothermal, hydrothermal-metamorphic) stage.

The first stage represents a precipitation of rock-forming and accessory mineral of highly evolved silicate and fluid-rich melt under magmatic crystallization via fractional crystallization, rapid undercooling and subsequent late- to early post-magmatic metasomatic replacement (albitization). Using of mineral geothermometers and geobarometers (biotite, quartz, zircon), we can estimate primary magmatic temperature of ca. 700 to 450 °C and pressure of 300–400 MPa.

The second stage represents subsolidus, mainly hydrothermal or hydrothermal-metamorphic overprint of the primary pegmatite assemblage. Secondary quartz, alkali feldspars, muscovite, chamosite, Be-minerals (phenakite and bertrandite; Uher et al., 2022), Nb-Ta-(Ti) oxides (pyrochlore-supergroup members, mainly microlite group, fersmite, rarely stibiotantalite and Nb-Ta-rich titanite), and native bismuth indicate temperature interval of ca. 400 to 250 °C and pressure under 200 MPa for this stage. The secondary subsolidus stage was probably connected with Variscan to Permian retrograde hydrothermal alteration of the pegmatites and/or Alpine (Cretaceous to Neogene) tectono-metamorphic overprint of the West-Carpathian Paleozoic crystalline basement in low-grade, greenschist metamorphic conditions (burial to uplift and nappe-stacking tectonic movements).

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'Fun with fault gouge' – on the excitement of dating prehistoric seismicity in the Alps using trapped charge methods on incohesive fault rocks

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This contribution presents results of ongoing efforts of unravelling ages of prehistoric seismic activity along large faults in the Alps by combining two trapped charge dating methods on quartz and K-feldspar contained in fault gouge. Fault gouges are incohesive fault-related rocks with a clay-rich matrix and subordinate clasts formed by pervasive frictional grain comminution in the core zone of mature faults at near-surface conditions (Fig. 1).

The classical approach when dating former earthquakes (mostly prehistoric ones, i.e., events that predate both instrumental and historical records), termed here 'classical paleoseismology', usually consists of studying coseismic surface ruptures (McCalpin, 2009).

a. b.

Figure 1. a. Outcrop of fault gouge derived from cataclastic granitoids along the Pustertal-Gailtal fault in the Austrian Alps (coordinates: 46.696°N, 12.688°E). The discrete colour change from white to black fault gouge suggests compositional variations. Length of green measuring stick is 1 x 1 m. Refer to Prince et al. (2024) for details. : b. Thin section photo of a freeze-dried component of fault gouge from the outcrop above, showing a large range of grain sizes of intensely fractured mineral and lithic clasts in a foliated clay-rich matrix; plane polarised light.

Ideally, this approach allows constraining minimum and maximum ages of former seismic events from displaced superficial (usually Quaternary) sediments, mostly by excavating trenches across-strike the faults in question. Such an approach is also capable of providing estimates on former earthquake magnitudes using empirical correlations between the observed surface displacements or rupture lengths and seismic moment release (Wells and Coppersmith, 1994). However, this approach is doomed to fail in case of the absence of young geomorphological markers and/or strata, such as in our study area in the Alps, characterised by rugged topography and high erosion rates. Such settings require what we term here a 'non-classical' paleoseismological method using ESR (electron spin resonance) and OSL (optically stimulated luminescence), two trapped charge dating methods.

Our studies focus on the eastern part of the largest fault systems in the Alps, the so-called Periadriatic fault system (PAF), between S Austria, NE Italy and N Slovenia (Fig. 2). The PAF system can be traced for about 700 km along-strike the entire Alps and forms an array of post-collisional, predominantly dextrally transpressive strike-slip faults that accommodated between 150 and 300 km of displacement between the Adriatic and European plates mostly in the Oligocene to mid-Miocene. GNSS data suggest that c. 3-5 mm yr^{-1} of N-S convergence are being accommodated between the Southern and Eastern Alps at present (Fig. 2). Instrumental earthquakes along the PAF are rare, but historical earthquake catalogues suggest that it could have hosted several damaging events with moment magnitudes Mw as strong as c. 7.0. Field studies along the PAF showed that fault gouge is often found in spatial proximity to pseudotachylites and cataclasites, i.e., cohesive fault rocks formed at greater depth than fault gouge. This testifies to the longevity of the PAF over several Ma. This, together with the observed discrepancy in fault activity on the timescale of 10^1 to 10^3 years (instrumental vs. historical seismicity), motivated us to expand the timescale to $10^4 – 10^6$ years using trapped charge dating on fault gouge.

The ESR and OSL dating methods rely on the accumulation of unpaired electrons within 'traps' (i.e., lattice defects) in minerals such as quartz and feldspar that can be released by different stimuli, such as light or heat. These electrons are produced over time mostly by the natural decay of radiogenic nuclides contained in the rocks. The trapped charges build up to reach a saturation level, after which they can be released from their traps either during periods of increased temperature due to shear heating, elevated stress and frictional grain comminution (Yang et al., 2019; Prince et al. 2024 and references therein). Therefore, they potentially allow direct dating of seismotectonic deformation in fault zones at near-surface conditions, requiring only the presence of suitable minerals in the sampled fault gouges, and with the assumption that at least a partial resetting of the ESR and OSL signal intensities occurred predominantly by coseismic shear heating.

Fault gouge samples were obtained from outcrops spanning a distance of c. 350 km along-strike the PAF system. We preferably sampled fault gouge in the proximity of Oligocene granitoids found in abundance along-strike much of the PAF, as these protoliths contained both quartz and feldspar. Since the saturation doses of the ESR signals on quartz are larger than the OSL signals on quartz and feldspar, ESR enables establishing a maximum age of the last resetting event of the system, while OSL allows constraining their minimum age when the signal is in saturation.

Dating results from 11 sites yielded ESR ages between c. 1.07 and 0.24 Ma and OSL ages ranging between c. 0.20 and 0.28 Ma. These ages are regarded as maximum and minimum ages at which partial resetting of signal intensities occurred due to earthquakes at each particular site. In combination, we conclude that major portions of the PAF system must have accommodated seismotectonic deformation in the last one million years.

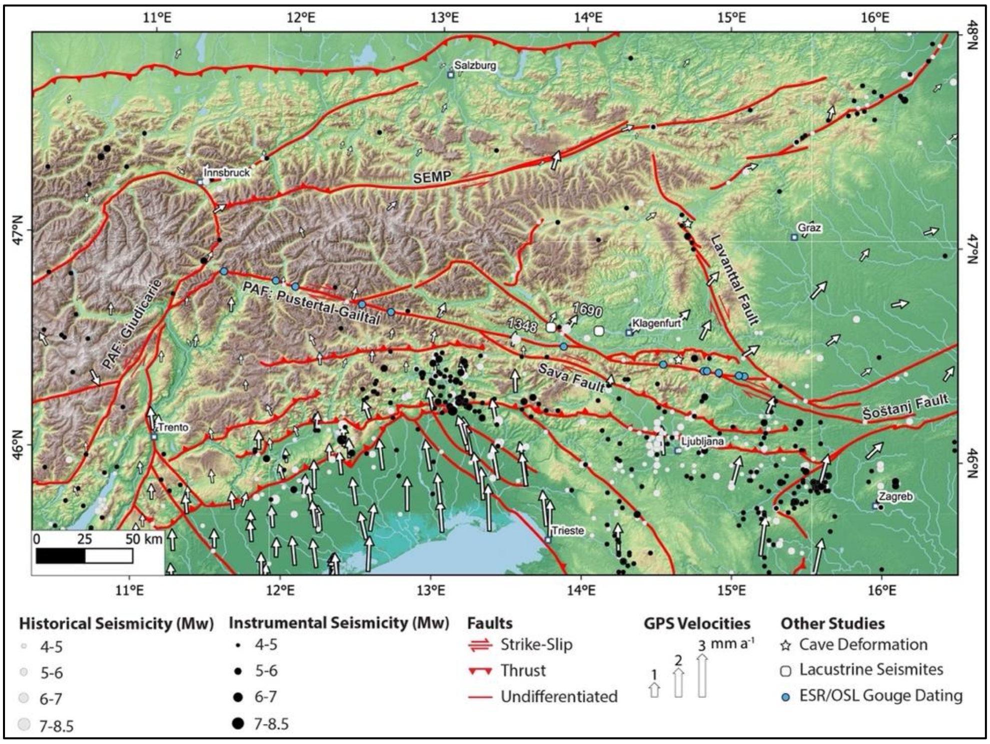

Figure 2. Topographic map of the Eastern Alps and northeastern Southern Alps with major Neogene faults superimposed in red. Historical earthquakes (1000-2006 AD) and instrumentally recorded earthquakes reveal a conspicuous absence of earthquakes along the PAF – with the notable exception of the 1348 Mw~7.0 and 1690 Mw~7.0 events in Friuli (NE Italy) and Carinthia (S Austria). GPS velocities are shown with white arrows. Sites of cave deformation studies along the PAF and Lavanttal Fault (e.g., Baroň et al., 2022), paleoseismic studies in Carinthian lakes (e.g., Daxer et al., 2022), and trapped charge dating of fault gouges indicating Quaternary fault activity (Prince et al., 2024) are shown as stars, white squares and blue circles, respectively. Refer to Prince et al. (2024) for references and further details

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Abstracts

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The role of micas in modelling ore-bearing greisen in Sardinia, Italy

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North Sardinia, Italy, is rich in granite-related ores that are potential prospects for W-Sn-Mo-Bi and F-REE. In the Oschiri area, mineralised greisen and hydrothermal veins are hosted at the intrusive contacts between the late-Variscan granites and their Variscan high-grade metamorphic host rocks. The greisen comprises K-feldspar, plagioclase and biotite hosted by white mica aggregates rimmed by quartz, sericite, and chloritoid. The ore minerals are (i) scheelite with wolframite-columbite, (ii) synchysite-Ce and xenotime-Y associated with thorite/uraninite, (iii) molybdenite dry veins with interstitial Bi-Te phases. The hydrothermal veins are composed of fluorite, galena and quartz. The two ore bodies are representative of an "F-rich open system" (Cossu et al., 2024; Pirajno, 2009), with greisenization taking place at $T \approx 400\text{-}300°C$, whereas hydrothermal fluids circulation occurring at $T < 300°C$ caused pervasive alteration of micas and remobilisation of elements that precipitated as ore minerals. White mica shows distinct zoning with darker cores and lighter rims, usually interfaced with chloritoid and quartz crystals. EMP analyses were conducted on 96 points on the cores and 106 points on the rims for F, Na, Mg, Si, Al, Ba, K, Cl, Ca, Mn, Ti, Ni, Fe, and Cr. The core and rims major elements have concentration (apfu) ranges of, respectively, Si 3.07-3.18 and 3.10-3.36, Al 1.74-1.90 and 1.59-1.85, K 0.84-0.95 and 0.83-0.98, Fe 0.11-0.28 and 0.14-0.46, Mg 0.0-0.04 and 0.01-0.10. This compositional variation is coherent with a Tschermak-type substitution [2Al=Si+Fe(+Mg)]. The data are consistent with a Fe-rich muscovite composition. Moreover, the resultant low wt. % total coupled with a slight charge-unbalanced structural formula raises the allegation of the presence of Li. The application of the in situ Rb/Sr dating method (Rösel et al., 2021) on the white mica rims will be used to constrain the mineralising event associated with greisenization and hydrothermal activity, integrating the ore system model, and giving us a precious interpretative tool for analogous geological settings and a new approach of dating granite-related ores.

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Paleomagnetic investigations of Neoproterozoic carbonates and tillites of Polarisbreen Group, Nordauslandet, Svalbard

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New demagnetization results from collection of 100 independently oriented palaeomagnetic samples, which represent Polarisbreen Group sediments: carbonates and tillites of Marinoan Cryogenian glaciation (Halverson et al., 2004), are presented. The paleomagnetic samples were collected in 2022 and 2023 from the Neoproterozoic sequence of Murchisonfjord (Western Nordaustlandet).

Principal component analyses revealed strong contribution of post-folding high-inclination palaeomagnetic component demagnetized up to 320°C. Calculated paleopole falls into Late Cretaceous – Paleogene – Neogene sector of Baltica Apparent Polar Wander Path. That suggests a possible relation of remagnetization with Late Cretaceous Svalbard magmatism (e.g., Senger et al., 2014). Great circle analyses point to the additional contribution of low-inclination component, potentially related to Caledonian remagnetization (compare Michalski et al., 2023). At this data processing stage no pre-Caledonian paleomagnetic record was recognized. Preliminary rock-magnetic results suggest the presence of maghemite and magnetite. All investigated samples were subjected detailed petrographic and mineralogical observations. Separated detrital zircons from tillites and adjacent quartzites were subjected to U-Pb age determinations.

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Production technology of early medieval ceramic crucibles in the light of mineralogical analyses. The case of finds from Wrocław (S-W Poland)

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Detailed studies on the production technology of ceramic crucibles, the way of their utilization are extremely rare. Our research tries to fill this gap in our knowledge. Early medieval sack and sherd crucibles, pottery from the Wroclaw settlement (SW Poland), and potential raw materials used for the production of ceramic masses were studied by polarized light microscopy, scanning electron microscopy coupled with energy dispersive X-ray spectroscopy, thermal analysis, and X-ray diffraction.

The results show that the sack crucibles are the most technologically advanced. They were made from carefully selected raw materials, most likely fine kaolinitic clay transported from deposits located several tens of kilometers to the southwest (the Bystrzyca River valley, Strzegom-Sobótka Massif), and fired at temperatures of at least 950°C. This origin of the clay confirms the presence of numerous lithic grains (granite) found in the sack crucibles. Kaolin has refractory properties that significantly improve the parameters at the high temperatures to which the crucibles are subjected. For this reason, kaolinitic clay was imported from faraway place. Alternatively, clay with graphite added was used to produce ceramic mass. The latter probably came from deposits located several tens of kilometers to the southeast, in the village of Zakrzów (Strzelin Massif). Graphite significantly increases the strength of crucible or vessel walls and has refractory properties. In contrast, pottery and potsherds used as crucibles are less carefully prepared using local clays, probably Mio-Pliocene so-called "Poznań Clays" exposed in the western part of Wrocław and fired at much lower temperatures not exceeding 700°C.

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Variation in the chemical composition of rocks within Neogene andesite suite, Pieniny Klippen Belt, Western Carpathians, Poland

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Neogene andesite rocks occur along the contact of the Pieniny Klippen Belt and the Magura Unit of Outer Carpathians (Birkenmajer, 2003). The age of magmatism in this region ranges from ca. 12.8 Ma to 10.8 Ma (Pécskay et al., 2015; Anczkiewicz & Anczkiewicz, 2016).

Although the chemical composition of Miocene andesites in the Pieniny area have been studied previously (e.g. Anczkiewicz & Anczkiewicz, 2016), more detailed analyses were performed to determine the tectonic environment of their emplacement. The above-mentioned authors suggest that these rocks were formed from partial melting of the metasomatized lithospheric mantle as well as magma derived from an enriched MORB type mantle.

The TAS chemical diagram showed two groups of compositions for the analyzed rocks. The magmatic rocks from the region between Kluszkowce and Krościenko nad Dunajcem are mainly characterized as trachyandesites and basaltic andesites, while those from the Szczawnica – Jaworki area are mainly andesites s*ensu stricto* and dacites. The trace element ratios in these rocks may indicate that they were formed on an active continental margin as well as that the magma sources might have been influenced by subduction.

The discovery of two different types of magmatism based on rocks' chemical compositions may indicate the existence of two magma chambers. The origin of Miocene magmatism in Pieniny Klippen Belt region, probably from two different sources, needs more sophisticated analyses in the future.

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Th-Pb dating of monazites – traces of 5th thermal event discovered in altered rocks of Jastrzębna IG-1 drill

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Monazite is a mineral unique for its capability to register subtle magmatic and metamorphic events, that would remain unnoted for a zircon or other minerals used for dating. This work is a documentation of one such event, discovered in thin sections extracted from Jastrzębna IG-1 drill (Eastern European Craton, NE Poland) containing monazites, which have been observed through a scanning electron microscope (SEM) and analysed further with chemical dating of Th-Pb isotopes by an electron microprobe (EMP/EPMA). This event, dated ~1,56 Ga, corresponds with one of AMCG magmatic episodes from mesoproterosoic. Samples used in this work were also used in another paper (Wiaderny, 2022), where author employed the same methods to document four other thermal episodes: 1,86 Ga, 1,79 Ga, 1,65 Ga and 1,46 Ga.

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Melt inclusions in eclogites as witnesses of elements deep cycles and mass transfer to the mantle

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Subduction controls the incompatible elements (e.g., Cs, Pb, Li, B) and volatiles (e.g., CO_2, Cl, F) deep cycles. Elements concentrated in the slab are subducted and then released in melts and fluids via dehydration and/or partial melting. Incompatible elements-rich fluids and melts interact with the overlaying mantle re-fertilizing it. During oceanic lithosphere subduction, the elements transferred in the mantle can be partly re-emitted into the atmosphere via arc volcanism. However, during continental crust subduction, the absence of volcanic arc is likely making the mantle a reservoir for crustal elements. Melts and fluids responsible for crust-mantle mass transfer can be directly investigated by targeting fluid and melt inclusions trapped in mantle bodies now hosted in deeply subducted rocks. Here we present examples of such melt inclusions-bearing rocks along with the information that they provide about the deep volatile cycles and mass transfer during crust-mantle interaction. The samples are the high-pressure (HP) eclogites hosted in garnet peridotite bodies surrounded by HP granulites of the Granulitgebirge and the ultra (U)HP eclogites hosted in diamond-bearing gneisses of the Erzgebirge, both in the Bohemian Massif (Germany). All these eclogites were involved in subduction and continent-continent collision during the Variscan orogeny. In these rocks melt inclusions occur in clusters in garnet, either as glass or polycrystalline with a mineral assemblage typical of nanogranitoids. The melt is granitic with a continental crust trace elements signature suggesting an external origin with respect to the hosting eclogites. This melt is responsible for mass transfer from the crust to the mantle and hence it is the perfect target to quantify elements mobilization. The content of CO_2, Cl and F in the melt were measured in situ and the results in some of these examples have shown high concentrations. Hence, volatiles mobilization from the crust and their storage to the mantle during continental crust subduction might have had an impact on the past global volatile cycles.

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Alpine granite duplex formed from two Variscan granite blocks in the Tribeč-Zobor crystalline basement: determination by age, mineral stabilities and structural data

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White mica Ar/Ar and zircon U-Pb SHRIMP geochronology, different mineral stabilities, particularly monazite and allanite, and structural data were used for deciphering of two juxtaposed Variscan granite blocks in the Tribeč-Zobor basement (Western Carpathians). Granites from the crest part in this crystalline basement represents metamorphosed/mylonitised monzogranite ca. 355 Ma in age. The underlaying subhedral granitic rocks formed in wider time span of origin ca. 358-348 Ma show S-and I- type affinity what indicate their affiliation to different Variscan block against to upper positioned metamorphosed ones. The underlaying subhedral S-type granodiorite with almost unaltered monazite are exposed below these aforementioned mylonitised granites which contain intensively broken down monazite with secondary mineral coronas. The absence of monazite recording Alpine tectonism in upper block suggests that the monazite originated during the Variscan post-magmatic cooling and not during the Alpine overprint. Monazite in the subhedral S-type granitic rock remained unaltered due to rapid cooling after emplacement into shallow crustal position. In contrast, the intensive monazite alteration observed in the upper positioned metamorphosed/mylonitized granites is interpreted as a result of slower cooling in a deeper crustal level. The Alpine monzogranite from crest part of the Tribeč-Zobor basement was metamorphosed under P-T conditions of 450-500°C, 7.5-8 kbar. An age of ca. 78 Ma, yielded by $^{40}Ar/^{39}Ar$ single grain fusion geochronology of muscovite, records the timing of the Alpine overprinting of monzogranite. The Alpine tectonically affected granites at age of ca. 78 Ma was thrusted over the Tatric Unit. The observed deformational structures in the crest monzogranites are related to the evolution of sinistral shear zones with NE–SW strike and subvertical inclination. The granites are influenced by plane strain, which is characterised by sub-horizontal to gently dipping spaced, to pervasive tectonic foliation to an NW or SE direction. Late Cretaceous to Paleocene shearing observed in these mylonitised granite shows NW – SE shortening, overall the Alpine stacking of the two Variscan magmatic blocks was subhorizontal. Structurally, the Tribeč-Zobor Variscan basement underwent different Variscan and Alpine evolution and can be interpreted as the Alpine Tribeč granite duplex.

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Peridotites of the Köli & Seve nappe complexes – comparison & implications for Baltican margin evolution during Caledonian Orogeny

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Orogenic peridotites provide valuable perspective on specific stages of the Wilson cycle. In this study, we present an in-depth comparison of the geochemical composition and mineralogy of mantle fragments from two nappe complexes of the Scandinavian Caledonides: Seve (SNC) vs Köli (KNC). The classical perception is that the SNC represents the farthest margin of Baltica, whereas the KNC represents terranes derived from the Iapetus Ocean. Our study aims to provide an updated understanding of the evolution of the Baltican margin throughout the Caledonian Orogeny based on the lithospheric mantle record and verify the main hypotheses on the origin of associated orogenic peridotites.

Detailed studies of the orogenic peridotites within SNC revealed their sub-oceanic, refractory character (modal and bulk chemical composition: e.g., Al_2O_3 and CaO <1wt. %) of common dunitic/harzburgitic spinel peridotites that underwent serpentinization on the ocean floor (lizardite-chrysotile serpentine mesh). The chemical composition of spinel cores ([Al-]chromite, Mg# = 30-45, Cr# = 65-85) is typical for those in suprasubduction settings, attesting to a subduction influence predating the serpentinization. Single serpentinized bodies were recrystallized into serpentine-free, Amph- and Chl-rich peridotites strongly controlled by local redox conditions (e.g. Ol Mg# in the range of 90.0-90.5 to 93.5-95.0 associated with chromite and magnetite, respectively). Garnet peridotites, comprising 3 amphibole generations showing continuous retrogression from Grt- down to Spl-facies (pargasitic to tremolitic compositions, respectively), point to a fluid-rich environment during subduction, followed by exhumation in similar, sub-oceanic setting (poorly developed lizardite-chrysotile serpentine mesh). The extremely enriched Sr isotopic composition of each amphibole generation ($^{87}Sr/^{86}Sr$ = 0.718-0.719, at the time of Caledonian emplacement) demonstrates association with ancient crustal material, indicating possible subduction of the Baltican continental margin underneath a nearby (Baltica-derived?) continental terrane. While the SNC appears to have witnessed a complex, 'accretionary'-style episode of the evolution of Baltica, peridotites from KNC show heavily serpentinized mantle of more typical, refractory sub-oceanic affinity (bulk Al_2O_3 and CaO <1.5 wt. %, Al-chromite spinel with slightly altered cores; Mg# = ~40, Cr# = ~55) without significant subduction influence. Such characteristics suggest an Iapetan origin of the bodies within KNC, but draw a sharp boundary between accretionary Baltican margin units (SNC) and a 'true' collisional oceanic suture (KNC).

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One mica to rule them all, one to bring them all: Variscan assembly of Tatra Mountain crystalline basement

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The metamorphic rocks of the Tatra Mountains' crystalline basement exhibit an inverted metamorphic sequence, with medium-grade Lower Unit (LU) rocks overlain by high-grade, often migmatized Upper Unit (UU) rocks. This study addresses the ambiguity of a boundary overthrust in the Polish Tatra Mountains through microstructural analyses and geochronology along profiles on Smreczyński and Trzydniowiański Mountains.

Field studies indicate (i) an increase in the degree of migmatization ascending the profile, (ii) variations in strain, but (iii) no significant lithological differences. The ductile F2 isoclinal folding event is associated with the formation of subhorizontal S2 foliation, overgrown by low-strain white mica perpendicular to the foliation. This fabric is overprinted by F3 folds with subvertical axial planes parallel to NE-SW trending faults. The rock microstructures and the strength of quartz crystal-preferred orientation (CPO) across the profile suggest the presence of three high-strain ductile deformation zones. CPO symmetry is consistent with prism <a> and prism <c> slips during high-T simple shear, which aligns with the retrograde migmatization conditions estimated by thermodynamic models (~0.7 GPa; >650°C).

Both $^{40}Ar/^{39}Ar$ and Rb/Sr geochronology were performed *in situ* on mica defining the ductile structures. The majority of $^{40}Ar/^{39}Ar$ dates are centered around ca. 340 Ma (n: 44/60), with some dates dispersed towards ca. 310 Ma (n: 16/60). Most Rb/Sr dates (n: 94/149) show a similar dispersion from ca. 345 Ma to ca. 305 Ma. These patterns reflect date resetting, possibly during Variscan metamorphism that crystallized low-strain white mica. A second population of Rb/Sr dates (n: 55/149) from one rock proximal to a brittle fault provides evidence of an Alpine overprint at ca. 90 Ma, resulting in replacement of biotite by chlorite.

Our results confirm Variscan shear deformation, which may be associated with the tectonic juxtaposition of LU and UU. However, the (i) lack of significant lithological differences, (ii) presence of multiple high-strain zones, and (iii) uniform geochronological record challenge the existence of the crustal-scale thrust separating these units, and suggest a need for revision of the tectonostratigraphy of the Tatra Mountains in Poland.

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Rock the Redox Reaction: Unraveling High-Pressure Dehydration and Carbonation of Serpentinites in Subduction Setting

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High-pressure interactions between aqueous fluids and subducting crustal and mantle rocks play a key role in altering deep volatile recycling. This study addresses the significance of redox reactions during subduction metamorphism through microstructural and geochemical analyses, coupled with thermodynamic modeling of high-pressure fluid-rock interactions. We focus on the Cerro Pingano ultramafic massif (Sierra de Baza, Spain), which contains Atg-serpentinites, Atg-Chl-Opx-Ol rocks, and Chl-harzburgite, all hosted within a sequence of graphite-bearing metapelites and marbles.

A transition from Atg-serpentinite to Chl-harzburgite is traced across two ~50 cm wide reaction fronts oblique to the rock fabric. While this transition suggests closed-system deserpentinization beyond antigorite stability, the decrease in the bulk $Fe^{3+}/\Sigma Fe$ ratio and the presence of magnesite in Chl-harzburgites indicate open-system fluid-rock interaction. The orientation of the magnesite $[0001]_{Mgs}$ axis, similar to those of olivine, orthopyroxene, and tremolite $[010]_{Ol,Opx,Tr}$, along with its textural equilibrium with Ol-Opx-Tr-Chl, attests to high-pressure carbonation. Thermodynamic models simulate the infiltration of electrolytic fluid from the nearby metapelite into the serpentinite and validate the influx of reducing, C-bearing fluids across the reaction fronts. A modeled influx of less than 10 moles of fluid (<0.2 weight fluid/rock ratio) explains the observed (i) propagation of redox reaction fronts, (ii) the recrystallization of Atg-serpentinite into Chl-harzburgite, and (iii) the coupled reduction and carbonation of Chl-harzburgite.

Our reduction-carbonation model demonstrates that serpentinites are highly reactive lithologies in subduction zones, capable of buffering the redox capacity of external fluids and capturing carbon at high pressure. This highlights (i) the significance of redox reactions during subduction metamorphism, (ii) the need to consider open-system chemical exchange, and (iii) the applicability of modern thermodynamic models of electrolytic aqueous fluid speciation and open-system infiltration. We infer that records of prograde metamorphic reactions may reflect changes in redox conditions, not necessarily linked to variable P-T conditions.

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Metamorphic record of metapelites from AMINV K-1 borehole near Kobierzyce (Lower Silesia, Poland)

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The Variscan basement of the Fore-Sudetic Block is scarcely exposed and the evolution of its metamorphic units is still unclear. Therefore, the AMINV K-1 borehole, located near Kobierzyce, approx. 20 km SW of Wrocław, gave us a unique insight into the basement geology. The drilling, performed in 2013, sampled the crystalline rocks at depth interval of 100.00 - 434.80 m below the surface. The drillcore exposes a diverse metasedimentary sequence dominated by mica schists, often rich in garnet. In our study, we examined these rocks in order to describe their metamorphic evolution and to correlate their regional position.

SEM and EMPA observations revealed some interesting features of the studied metapelites: 1) chemical zoning of garnet, with the Mn-rich core marking its growth during progressive metamorphism; 2) numerous mineral inclusions in garnet, e.g. chloritoid, white mica, kyanite, rutile; 3) diverse chemical composition of white mica, including phengite. Results of thermodynamic modelling indicate that the P-T record of the studied rocks evolved during at least two stages of metamorphism. The presence and chemical composition of chloritoid, phengite and garnet indicate that high-pressure low-temperature metamorphic (HP-LT) episode M1 predates the pervasive MP-MT metamorphism M2. Results of quartz-in-garnet Raman elastobarometry show maximum inclusion entrapment pressures of approx. 16-18 kbar, supporting the modelling results for the M1 event.

Our results provide a unique description of the Variscan metamorphism recorded in the crystalline basement of the Fore-Sudetic block. The HP-LT metamorphic record and other petrological features of the studied rocks match those of their counterparts in the Kamieniec Metamorphic Belt (KMB; Szczepański et al., 2022), suggesting that the KMB may extend further north.

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Magmatic and hydrothermal metal migration in the oceanic lithosphere: implications for the Polish contract area at the MAR (26–33°N)

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Slow-spreading ridges host significantly larger seafloor massive sulfide (SMS) deposits compared to fast-spreading ridges. The highest-tonnage SMS deposits occur in plutonic rocks of oceanic core complexes (OCCs), which expose lower crust and mantle rocks to the seafloor via detachment faults. All seven International Seabed Authority (ISA) contractors for sulfide exploration, including Poland, operate in slow- to intermediate-spreading ridge segments with OCCs. The slow-spread oceanic crust is thinner and more heterogeneous than the fast-spread crust, influencing sulfide differentiation and metal transport as we demonstrate in this study on various OCCs and ophiolites.

In the Atlantis Bank OCC (57°E, Southwest Indian Ridge), sulfides differentiate primarily through fractional crystallization, accumulating in the lower parts of gabbroic bodies. In contrast, at the Kane Megamullion OCC (23°N, Mid-Atlantic Ridge), lower magma supply results in sulfide enrichment via melt-mantle reactions, particularly at gabbro-peridotite contacts near the seafloor. Our studies of the Central Sudetic and Oman Ophiolites, including sulfur isotope and sulfide mineralogy analyses, indicate that seawater hydrothermal circulation typically affects only the upper 2 km of the lithosphere. Deeper hydrothermal processes are limited to post-magmatic fluid horizons, making large-scale leaching less effective below 2 km below the seafloor. Our results may explain why large SMS deposits are more common in slow-spreading lithosphere with low magma supply.

These findings will aid in the search for SMS deposits in the Polish contracted area, where low magma supply influences lithospheric structure. During the first Polish expedition in 2022, multi-beam bathymetry, backscatter, and sub-bottom profiling were used to map three known OCCs (Atlantis Massif, Southern OCC, Dante's Domes) and two newly identified OCCs. Autonomous Underwater Vehicles have since provided high-resolution bathymetry and geophysical data, with sample collection using Remotely Operated Vehicles planned for 2025.

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In situ and remote sensing mapping of the Atacama desert in Chile: ore prospecting in Mars Analog

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Ore prospecting around the world is becoming more and more efficient thanks to the high-quality satellite images availability. The aim of the presented research is to merge information from geological mapping in situ with satellite images analysis, and to find ore minerals detection threshold. The study area was Sierra Gorda open-pit mine area in the Atacama Desert in Chile – the Mars analog. Sierra Gorda belongs to the KGHM International mining company – one of the largest copper ore mine in the world. We used the Sentinel-2 satellite data due to their good spatial and time resolution. Different remote sensing techniques were applied. On the resulting maps, the study area with ore minerals presence, found during geological mapping, coincides in indexes values with active mine. We believe that presented method can be used at the preliminary stage for ore prospecting on Earth, on the Moon, on Mars and perhaps on asteroids in the future.

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Is spherulitic hematite evidence of highly acidic conditions created in extreme terrestrial environments and potentially on Mars?

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Hematite (α-Fe_2O_3) of spherulitic and botryoidal shape was found as the last phase crystallizing at the burning coal-waste dumps at fissure mouths in Radlin, Chwałowice and Czerwionka in the SW part of the Upper Silesian Coal Basin and, in the NW part, the Wełnowiec dump. It was also recorded in the Gruta con lago cave formed due to sulfuric acid speleologenesis within the Mulapampa travertine deposits in the vicinity of the active Ampato-Sabancaya Volcanic Complex (the Western Cordillera in the Peruvian Andes). Hematite spherules are also known from the surface of Mars, where they constitute one of many intriguing features commonly known as “blueberries”, and their origin is still a matter of open discussion.

For the purpose of replicating the formation process of the hematite spherules and detailing the conditions required for their formation at dynamically changing physicochemical conditions occurring at the burning coal-waste dumps, several laboratory experiments were undertaken. Reactants there represented substrates and products observed during hematitic spherule formation on the burning coal-waste dumps, and were goethite α-FeOOH, salammoniac NH_4Cl, elemental sulphur S_8, phtalimide $C_8H_5NO_2$, $FeSO_4 \cdot 7H_2O$, naphthalene $C_{10}H_8$, water steam, NaCl, $AlCl_3$, $FeSO_4$, $MnSO_4$, HCl, and powdered coal waste from the Radlin dump. The experiments were conducted under laboratory conditions in a Binder heating chamber ED23 and a laboratory tubular furnace in open and semi-closed systems. Temperatures at 150, 200, 450-500, 600-650, 700, and 900°C were used, and assigned times were 90 min, 5 h, 78 h, 90 h, 7, and 16 days. Experiments in solution were conducted at pH from neutral to 0 (Ciesielczuk et al., 2024).

The experiments proved that apart from the supply of iron and oxygen, an extremely low pH stands as crucial for the formation of hematite in the shape of a spherule. What is more, such very acidic pH was also measured by the sampling sites on the dumps where spherulitic and botryoidal shape hematite were found. Finally, we conclude that such a low pH can be created locally or regionally in extreme environments, including other planets.

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Geochemical and isotopic signatures reveal the complex origin of peridotite-hosted carbonates (Central-Sudetic ophiolites, SW Poland)

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In this study, we investigate carbonates hosted by the two ultramafic massifs (Szklary and Braszowice) of the Central Sudetic Ophiolite (CSO) (NE Bohemian Massif). This ophiolitic complex represents a late Devonian oceanic lithosphere formed in the slow-spreading regime. The complex story of the CSO includes prograde metamorphism, reaching its climax within the amphibolite facies, emplacement of syn- and post-Variscan magmas, as well as tropical weathering event(s) in the Cenozoic.

Carbonate mineralization appears mostly as extensive veins and vein-like structures within partially serpentinized peridotites and serpentinites. The vast majority of veins in both localities exhibit a high modal abundance of cryptocrystalline magnesite accompanied by chalcedony or quartz. Field investigations revealed that carbonate veins containing magnesite-dolomite and calcite-dolomite are comparatively less common occurrences and they are mostly seen in the Braszowice ophiolitic fragment. In some samples, hydrous magnesium silicates co-occur with the studied carbonates. Based on both bulk and single-spot chemical composition (ICP-MS/ES and LA-ICP-MS) of carbonates, discrepancies and similarities have been observed between two ultramafic massifs. The concentrations of several trace elements (Ni, Al, Mn, Sr, Ba, Fe) noticeably vary between Szklary and Braszowice. Moreover, varied chemical compositions have been pinpointed among veins sampled at different depths. Strontium isotope composition was analyzed for fraction dissolved in HCl. At least two groups of carbonate veins can be distinguished based on their $^{87}Sr/^{86}Sr$ ratios. Veins sampled from the Braszowice pit floor, exhibiting Mgs or Mgs± Dol or Cal ± Dol paragenesis, consistently display 0.7064 - 0.7065 values. Carbonate veins located in shallow depths in Braszowice and Szklary, primarily composed of cryptocrystalline Mgs or Mgs ± Qz, show $^{87}Sr/^{86}Sr$ values ranging from 0.7070 to 0.7113 suggesting input from fluids derived from the continental crust.

Our research indicates a level of complexity in the formation of ophiolite-hosted carbonates including several stages of their formation as well as several sources of carbonating fluids.

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Ex situ mineral carbonation of serpentinized peridotites: CO_2 storage and a small step towards Ni recovery

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Peridotites and serpentinites (ultramafic rocks) are considered highly promising substrates for mineral carbonation, facilitating the long-term and stable storage of anthropogenic CO_2. The primary advantage of these rocks is their high concentration of Mg^{2+} cations, which can easily bond with CO_3^{2-} ions to form stable magnesium carbonates. Another feature of ultramafic rocks is the relatively high nickel content reaching up to 10.000 mg/kg (Kierczak et al., 2021). We conducted an ex situ aqueous experiment using serpentinized peridotite from the Central Sudetic Ophiolite to trace the mobilization of Ni^{2+} during the mineral carbonation process.

The carbonation experiment was performed in a batch reactor with powdered rock samples under conditions of 185°C and 100 bar pCO_2 for 96 hours. Despite using ultrapure water at a water-to-rock ratio of 10:1, no additional buffering agents were employed.

Triplicate analysis (ICP-OES) of cation concentrations in the post-experimental leachate revealed an average nickel concentration of 17.6 mg/kg. Examination of the solid products indicated that nickel is also present in phyllosilicates crystallized during carbonation, with NiO content reaching 35 wt. % (SEM-EDS). Geochemical modelling showed that the solutions reached equilibrium with Mg-saponite (SI=13.98) after 96 hours, with Ni^{2+} being the predominant species in the H_2O-CO_2 system at pH 6.55 and 185°C. Consequently, Ni^{2+} probably substituted for Mg^{2+}, resulting in Ni-phyllosilicates crystallization.

The results of the experimental phase suggest that Ni-phyllosilicate formation can be integrated with ex situ mineral carbonation of ultramafic rocks. Although the crystallization mechanism of nickel phyllosilicates has not yet been fully characterized, this process may be a small step toward developing a novel method for nickel recovery.

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Geochemical diversity of Lower Palaeozoic island arc magmatism in the Iapetus Ocean: The Köli Nappe Complex, Swedish Caledonides

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The Köli Nappe Complex (KNC), an volcano-sedimentary assemblage within the >1200 km long Upper Allochthon (UA) of the Scandinavian Caledonides, originated as terranes within the Iapetus Ocean basin (Stephens, 2020). In Västerbotten, Sweden, the Björkvattnet (lowest), Stikke, Atofjället and Krutfjellet (highest) Nappes of the KNC are dominated by flysch, but each nappe hosts latest Cambrian (Carter et al., 2023) mafic to acid metavolcanites. The upper two nappes also host early Silurian gabbro and granite that signify major lithospheric extension. They show typical intra-oceanic arc trace element patterns, but there are consistent and systematic differences. εNd clearly discriminates between all the nappes; through the lower three nappes εNd for the late Cambrian metavolcanites is positive and has a strong negative correlation with $(La/Sm)_N$ indicating a change from N-MORB with less radiogenic Nd in the Stikke and Atofjället Nappes, to transitional and E-MORB affinities with more radiogenic Nd in the Björkvattnet Nappe. Silurian gabbros in the Stikke Nappe fall on the same trend at positive εNd values. In contrast, all the Krutfjellet Nappe samples of both age groups show negative εNd, which may indicate a source enriched in ancient continental material or the influence of a higher metamorphic grade with anatexis of the host metasediments. Whole-rock Pb isotopes show no clear correlation with εNd; instead, each nappe displays a range of values for $^{207/204}$Pb and $^{208/204}$Pb, with the Stikke Nappe showing the smallest range at the least radiogenic values. For the late Cambrian metavolcanites, $^{206/204}$Pb is positively correlated with $^{207/204}$Pb, which discriminate between the lower three nappes for late Cambrian metavolcanites, suggesting a mantle-like source with varying upper crustal contributions, perhaps derived from the host flysch. Overall, the metavolcanites in the lower three nappes represent distinct elements of an intra-oceanic arc complex in the Iapetus Ocean basin, each being a tectonic sample of magmatic rocks sourced from different mantle source regions. The highest (Krutfjellet) nappe is distinctly different, but magmatic versus metamorphic influences cannot yet be deduced unambiguously.

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Monazite dating results from mica schist of the Lower Unit of the Western Tatra Mts.

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The crystalline basement of the Tatra Mountains belongs to the northernmost part of the Tatric unit of the Western Carpathians and is composed of pre-Mesozoic crystalline rocks overlain by a Mesozoic and Cenozoic sedimentary cover and nappes. Metamorphic rocks are the most abundant in the western exposures of the basement in the Western Tatra Mts. They display an inverted metamorphic sequence with high-grade rocks in the hanging wall (Upper Unit; peak condition: 1.6 GPa, 750-800°C; Janák et al., 1996) and lower-grade rocks in the footwall (Lower Unit; peak condition: 0.6-0.8 GPa, 640-660°C; Janák et al., 1996) separated by a mid-crustal thrust fault. Here we report new age data on the monazite in the mica schists from the kyanite-staurolite and kyanite-fibrolite zones of the Lower Unit.

Yttrium, Nd, Ca and Th maps have been prepared for the correct interpretation of the metamorphic evolution of monazite. A simple core-rim zoning has been observed in some of the monazite grains, whereas in others the mapped elements appear to be homogeneously distributed throughout the grains. LA-ICP-MS U-Pb geochronology was applied to analyze 90 spots in 56 monazite grains from 6 samples. The calculated single dates slightly differ among the samples as well as within the sample but they show no obvious correlation with the distribution of mapped elements. However, there is a difference in age depending on samples location. The monazites from the kyanite-staurolite zone yield ages of 318 ±5.7 – 323 ±6.1 Ma, whereas those from the kyanite-fibrolite zone gave ages of 330 ±2.7 - 335 ±5.9 Ma. This suggests an upwards increase of metamorphic age as well as P-T conditions, thus resembling a Himalaya-type tectonometamorphic inversion.

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Sr-Nd isotope geochemistry of mafic microgranular enclaves from the eastern part of the Strzegom-Sobótka massif (SW Poland)

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The Strzegom-Sobótka massif is the largest of the granitic plutons in the central part of the Fore-Sudetic Block (NE part of the European Variscan Belt). It is composed of four main types of granite: hornblende-biotite granite, biotite granite, two-mica granite and biotite granodiorite (Pin et al., 1989; Puziewicz, 1990). Here we present new Sr–Nd isotope data from mafic microgranular enclaves hosted by biotite granodiorite.

The initial $^{87}Sr/^{86}Sr$ ratio of the host granodiorite ranges from 0.7058 to 0.7059 at an age of 300 Ma (Turniak et al., 2014), and the $^{87}Rb/^{86}Sr$ ratio changes from 1.24 to 1.26. The $^{87}Sr/^{86}Sr(i)$ values for the enclaves range from 0.7054 to 0.7060 and the $^{87}Rb/^{86}Sr$ ratio values are 0.92–1.77. For the host granodiorite, initial $^{143}Nd/^{144}Nd$ values range from 0.512374 to 0.512385 and εNd(t) from -3.1 to -1.8; similarly, these values are 0.512390–0.512472 and from -2.9 to -1.8 for the mafic microgranular enclaves.

Our isotopic data for the biotite granodiorite are in agreement with those of Pin et al. (1989), when the latter are recalculated to 300 Ma.

The enclaves generally have isotopic data close to or in the range of that from the granodiorite. Petrographic observations demonstrate that enclaves represent blobs of hybrid magma formed as a result of mingling with more felsic host melt (Domańska-Siuda & Bagiński, 2019). This may indicate that the enclaves and the host granitoid reached isotopic equilibrium at the emplacement level. Therefore, it is likely that the isotopic data obtained from the enclaves reflect the protolith signature of the granitoid in which they occur.

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Imaging of biogenic fluorapatite using fluorescence microscopy

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Minerals of the apatite supergroup occur as accessory phases in nearly all rock types and are important components of biogenic materials, including conodonts. Conodont elements are millimeter-sized, tooth-like structures composed primarily of fluorapatite. They are important paleoenvironmental archives and help to decipher past climate changes through oxygen isotope analyses. Conodonts typically consist of three distinct hard tissue components characterized by different geochemical signatures that can be investigated using *in situ* techniques. Since characterization of individual components using optical or scanning electron microscopy has proven inefficient for the optimal selection of targets for analysis, we tested the application of fluorescence microscopy imaging for this purpose.

Members of the apatite supergroup often exhibit fluorescence with varying emission colors and intensities. It has been shown that the fluorescence of conodont elements can be correlated with their degree of maturation, although significant intra-element variations are also observed (Mastalerz et al., 1992). Therefore, we tested a fluorescence microscope for imaging of polished conodonts embedded in epoxy resin as a complementary tool for assessing chemical and isotopic variability seen in datasets obtained by *in situ* analyses. We developed a preliminary methodology to record the fluorescence properties of conodonts excited by visible light in two wavelength regions: 460–490 nm and 533–558 nm.

We collected fluorescence data from three different genera (*Semiacontiodus*, *Baltoniodus*, and *Drepanoistodus*) extracted from Ordovician strata in Estonia. The results demonstrated that fluorescence properties do not solely correspond to the degree of conodont maturation; they are also taxon-specific and allow the distinction of internal features in conodont tissues. We conclude that fluorescence microscopy imaging shows a great potential in guiding target selection for *in situ* chemical and isotopic measurements.

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Carbon and oxygen isotope evidence for dolomite-related nephrites formation at the expense of organic matter-rich carbonates

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Stable C and O isotope composition of calcite inclusions, and O isotope composition of rock-forming tremolite, of two distinct dolomite-related nephrites, was determined. We examined green nephrite from the Złoty Stok deposit in the Sudetes (SW Poland), and greenish-white nephrite from the Yurungkash River deposit in the Western Kunlun Orogen (Xinjiang, NW China). In the case of the Złoty Stok deposit, C and O isotope composition of calcite and dolomite from wall-rock marbles was also determined. Calcite and tremolite from Złoty Stok nephrite show a large spread of $\delta^{18}O$ values, i.e., +7.0‰ to 20.4‰ and +3.6‰ to +10.9‰, respectively. Calcite from Złoty Stok nephrite is characterized by negative, variable $\delta^{13}C$ values ($\delta^{13}C$ span -16.0‰ to -9.1‰). Isotopic composition of wall-rock marbles ($\delta^{13}C_{carbonate}$ = +0.1‰, $\delta^{18}O_{carbonate}$ spans +20.7‰ to +23.2‰) from Złoty Stok is consistent with Precambrian and Phanerozoic marine carbonates. An isotopic composition of calcite ($\delta^{13}C$ = -14.9‰, $\delta^{18}O$ = +18.7‰) and tremolite ($\delta^{18}O$ = +1.9‰) from Yurungkash River nephrite is similar to the isotopic composition of Złoty Stok nephrites.

Oxygen isotope composition of calcite and tremolite from examined nephrites spans from $\delta^{18}O$ values slightly lower than O isotope composition of igneous rocks ($\delta^{18}O$ span +5.5‰ to +10.2‰; Taylor 1968), to $\delta^{18}O$ values of host-marbles, which is consistent with the marble transformation into nephrite under the influence of fluids triggered by intrusion. However, $\delta^{13}C$ values of both examined nephrites are much lower than $\delta^{13}C$ values of marbles. Nephrites $\delta^{13}C$ values are intermediate between near-zero $\delta^{13}C$ values of sedimentary carbonates and highly negative $\delta^{13}C$ values of metamorphosed organic matter ($\delta^{13}C$ span -25.8‰ to -10.8‰; McKirdy & Powell, 1974). This leads to a conclusion that nephrite (tremolite) preferentially precipitates from the fluids when they reach an organic matter-rich horizon in marbles.

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Charactristics of organic matter in Ediacaran siderite-bearing sedimentary rocks from the East European Craton

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In this study Ediacaran–Cambrian siliciclastic rocks from the western part of East European craton have been investigated. Samples were collected from drill cores and one outcrop in the St. Petersburg area (Russia), Lithuania, and Belarus. The pedogenic siderites, formed under reducing conditions in waterlogged soils, are found in greenish to gray mudstones and siltstones.

Organic matter (OM) for the study was extracted with a dichloromethane - methanol mixture (1:1 v:v) using an accelerated Dionex ASE 350 solvent extractor, and then analysed by gas chromatography-mass spectrometry (GC–MS). The siderite-bearing and intercalated siderite-free rocks are organic lean (TOC <1%) and exhibit a similar composition of OM. The main constituents of extractable OM were hopanes, *n*-alkanes, and *n*–fatty acids. Steranes were present in low concentrations with a low C27/C29 ratio – this indicates a predominant origin from green, photosynthetic algae. The values of the homohopane C_{31} S/(S+R) ratio did not exceed 0.34, which characterizes the immature sample, below the oil window stage of OM maturation. Long-chain odd-carbon-number n-alkanes dominate in some siderite-bearing samples, reflecting the presence of terrestrial-type OM. Biomarker indices, including the Carbon Preference Index (CPI) and the Terrestrial/Aquatic Ratio (TAR), indicate a significant contribution of terrigenous organic material with notable inputs from prokaryotic organisms.

The results indicate that pedogenic siderite formation in the Ediacaran–Cambrian siliciclastic rocks from Baltica was driven by microbial processes in a freshwater environment. These findings have significant implications for our understanding of Ediacaran sedimentary environments. They highlight the crucial role of early terrestrial ecosystems in siderite formation and underscore the complex interactions between organic matter, mineralisation processes, and soil microbial communities in Ediacaran tropical wetlands.

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Isotope and chemical study of atmospheric greenhouse gases and other traces in a municipal waste treatment plant

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Greenhouse gases (GHGs) and non-GHG air pollutants, are widely distributed and originate from landfill operations and waste processing facilities. This study involved multiple campaigns in 2021–2022, including continuous ground-based monitoring of CH_4 and CO_2 concentrations and their stable carbon isotope ($\delta^{13}C$) analysis, and trace compound quantification on a landfill site (Bezyk et al., 2024). The LGR-ICOS™ M-GGA-918 portable system for real-time measuring CO_2 and CH_4, and in-situ portable Fourier-Transform InfraRed (pFTIR) multi-gas spectrometer (GASMET DX4000 system) for the simultaneous measurement of organic and inorganic compounds at emission hotspots were used. The laboratory-based instrumentation included Picarro CRDS (Model G2201-i) for determining the isotope signatures of CO_2 and CH_4. The results indicated that a few individual sources of GHGs were predominant within the waste processing facility, showing seasonal differences across the site. In the vicinity of the main emission sources inside the facility, a rise in the ground-level CH_4 concentrations was detected, from about 30 to 56 ppmv. As CH_4 concentrations were generally higher at the ground level in hotspot locations, along the facility's boundary the values were relatively lower, ranging from 2 to 9 ppmv. The related $\delta^{13}C$ analysis revealed the extent of the emission plumes downwind of the hotspots, which were characterized by atmospheric CH_4 depleted in ^{13}C by a 4‰. CH_4 emissions from extraction wells in active quarters had a distinct isotopic signature (-58.3 ±1.1‰) compared to biogas produced in the biological waste treatment installation (-62.7 ±0.7‰). Most of the trace chemicals found near the ground surface, including halocarbons, oxygen-bearing organic gases, ketones, nitrogenous and sulfurous gases, were associated with the CH_4- and CO_2-hotspot areas. Our findings imply that the organic and inorganic compound concentrations at waste processing facilities do not significantly affect the surrounding air quality, despite the relatively large variability in those concentrations.

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Origin of Kłodzko-Złoty Stok and Jawornik intrusions magmas: Insights from stable H, C, O and Cl isotope composition

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Ca. 340 Ma, Kłodzko-Złoty Stok pluton and Jawornik granitoid veins were subjected to the Cl content, and H, C, O and Cl isotope ratio analyses. Both suites are located in the Central Sudetes, at the NW margin of the Śnieżnik Massif. Mantle-derived intrusives (pargasite clinopyroxenite, lamprophyre, lamprophyric melt-derived syenite) are abundant in Cl (52–130 ppm), and are characterized by a broad range of δD values (-84‰ to -65‰), and narrow spans of $\delta^{13}C$ ($\delta^{13}C_{calcite}$ = -12.7‰ to -8.7‰), $\delta^{18}O$ ($\delta^{18}O_{diopside}$ = +7.7‰, $\delta^{18}O_{calcite}$ = +10.1‰ to +12.0‰), and $\delta^{37}Cl$ (-0.6‰ to -0.3‰) values, the latter being negative. Monzonites are rich in Cl (712–778 ppm), and show a broad range of δD (-78‰ to -63‰) and $\delta^{37}Cl$ (-0.2‰ to +0.4‰) values. Representative granodiorite is abundant in Cl (134 ppm Cl), its δD value = -69‰, $\delta^{18}O_{quartz}$ = +7.1‰ and $\delta^{37}Cl$ value = +0.2‰. Jawornik granodiorites are poor in Cl (24–25 ppm), and are characterized by a constant δD (-70‰ to -67‰) and $\delta^{37}Cl$ ($\delta^{37}Cl$ = -0.3‰) values, and a narrow range of $\delta^{18}O$ values ($\delta^{18}O_{quartz}$ = +8.2‰ to +9.2‰). Ultramafic and alkaline rocks of the Kłodzko-Złoty Stok pluton have $\delta^{37}Cl$ values similar to the upper mantle (mantle $\delta^{37}Cl$ span -0.5‰ to +0.1‰; Sharp et al., 2013), although their $\delta^{18}O$ values are higher and $\delta^{13}C$ values lower, relative to the mantle, which suggests a crustal component. Intermediate to felsic rocks of the Kłodzko-Złoty Stok pluton have similar $\delta^{18}O$ values, whereas higher Cl contents and $\delta^{37}Cl$ values (with a predominance of positive values), relative to ultramafic and alkaline intrusives. This suggests a contribution of the subducted slab, as seafloor serpentinites and high-temperature altered gabbros are abundant in Cl and have positive $\delta^{37}Cl$ values (Barnes et al., 2009; Barnes & Cisneros 2012). Higher $\delta^{18}O$ values of Jawornik granitoids suggest a lesser contribution of the mantle-derived material, whereas low Cl content and negative $\delta^{37}Cl$ value suggest a low input of the subducted slab and predominance of a crustal source.

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Monazite microstructures and textural implications of Prabuty charnockite – the thermal event recorded in the Dobrzyn Domain

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The greenish gray charnockite with poorly visible foliation was identified at the depth of 3894.6 m of the Prabuty IG1 borehole. This rare representation of rocks belonging to the structure of Dobrzyn Domain is contained within the East European Craton (southernmost Baltic Sea region). Petrological study of thin sections revealed relicts of orthopyroxene, frequent myrmekite, sericitic alteration of feldspars, advanced chloritization and interstitial pyrite. Monazite crystals showed several internal patterns – concentric oscillation (magmatic-like), dissolution-reprecipitation microstructures, rims and homogeneous composition. The metamorphic peak temperature was estimated on the preserved parts of orthopyroxene (765–750°C). The following retrogression was recorded on altered orthopyroxene (720–608°C) and chlorite (520–530°C). The results of chemical dating of distinct groups of monazite showed: isochronal age – 1499 Ma ±26.9 Ma or weighted average age – 1470 Ma ±20 Ma (concentric monazite); isochronal age – 1462 Ma ±8.3 Ma or weighted average age – 1468 Ma ± 8,4 Ma (metamorphic monazite). The chemical ages correspond to U-Pb ages obtained on zircon metamorphic rims of 1499 ±12 Ma with cores of 1758 ±12 Ma (Krzemińska et al., 2017). Our study provide evidences of the thermal influence of the AMCG intrusions of the Mazury Complex on Paleoproterozoic rocks of the Dobrzyn Domain at early Mesoproterozoic. We indicate an example of different (but complementary) response of metamorphism in zircon and monazite from the same rock. Besides, the interstitial occurrence of pyrite or pyrite-coated monazite grains remain further investigation in toward possible fluid alterations.

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Metasomatic record in hornblendite from Bystrzyca Górna (the Góry Sowie Massif, Central Sudetes, SW Poland)

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The Góry Sowie massif (GSM) is a crustal domain composed of migmatitic paragneisses, with less abundant felsic granulites, metabasites, orthogneisses, meta-ultramafites and granitic pegmatites. The Bystrzyca Górna hornblendite is embedded together with serpentinite in the gneiss-hosted granulites. The rock consists of pargasite with phlogopite, F-rich apatite and allanite-(Ce), titanite and zircon. The geochemical data imply that melt was derived from a hydrous mantle source metasomatized by subducted slab–derived components, while the Zrn U-Pb dating yielded an age of 388.3 ±0.8 Ma (Ilnicki et al., 2019). However, the abundance of fluid-driven phenomena in the GSM led us to investigate the possible record of metasomatic activity in the hornblendite. We measured the bulk rock F and Cl contents, H and Cl isotope ratios, and O isotope ratios of the rock-forming pargasite. The O isotope composition of the zircons (mean $\delta^{18}O_{Zrn}$: +5.7‰) indicates their mantle origin (Ilnicki et al., 2019), whereas the O isotope composition of the pargasite ($\delta^{18}O_{Prg}$: +5.5‰ to +6.6‰) spans from the upper mantle to more crustal values. The H isotope composition shows a narrow range (δD value: –77‰ to –71‰), whereas the Cl isotope composition ($\delta^{37}Cl$ value: –0.1‰ to +0.7‰) and the F/Cl ratio (11.5–16.3) show a wider range. The most primitive hornblendite sample has the lowest $\delta^{18}O_{Prg}$ (mantle-like) and δD values, the highest F/Cl ratio, and a mantle-like $\delta^{37}Cl$ value (mantle $\delta^{37}Cl$: –0.5‰ to +0.1‰; Sharp et al., 2013). Elevated $\delta^{18}O_{Prg}$ values of the remaining samples suggest interaction with the crustal fluids. In turn, the elevated $\delta^{37}Cl$ values and the lowered F/Cl ratio (higher abundance of Cl) suggest input from slab-derived fluids. A possible source of the latter could be a dehydration of seafloor serpentinites or HT-altered gabbros, which are abundant in Cl and often have positive $\delta^{37}Cl$ values (e.g., Barnes & Cisneros, 2012).

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P-T-t conditions of Alpine metamorphism in the south Veporic unit, Western Carpathians

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The Central Western Carpathians represent a tectonic system that extends eastward from the Alps and may be well correlated with the Austroalpine units of the Alps. The pre-Tertiary complexes of the Central Western Carpathians originated during the Cretaceous collisional events following the closure of the Meliata ocean by Late Jurassic times. Alpine metamorphism, related to the development of a metamorphic core complex during Cretaceous orogenic events, has been recognised in the Veporic unit (Janák et al. 2001). Increasing *P-T* conditions from greenschist to middle amphibolite facies reflect a coherent metamorphic field gradient. To constrain the timing of prograde metamorphism we dated monazite using electron microprobe. The dated monazite occurs in semi-pelitic schists of the highest grade Alpine metamorphic zone, exposed from the deepest levels of the Veporic dome. The peak metamorphic assemblage consists of garnet + biotite + muscovite + paragonite + rutile + quartz. Garnet occurs as clusters involving the fragments of fractured (pre -Alpine) garnet, and newly-formed, idioblastic Alpine garnet. Alpine garnet is zoned with decreasing Ca (X_{Grs} = 0.23-0.16) and increasing Mg (X_{Prp} = 0.05-0.12) from the core to the rim. Thermodynamic modelling suggests that Alpine garnet grew during the burial (up to 1.2-1.4 GPa; 580-600°C). The metamorphic *P-T-t* path is "clockwise", reflecting post-burial decompression (down to 0.8-0.1; 600-610°C) and cooling during Alpine orogenic cycle. Monazite occurs in the matrix occasionally associated with allanite (REE-epidote) and xenotime, suggesting monazite formation via allanite breakdown during the prograde P-T path. Chemical Th-U-Pb dating yielded Cretaceous age of 95.8 ±2.7 Ma (MSWD = 1.13). This timing is in excellent agreement with intracontinental subduction and HP/UHP metamorphism in the Austroalpine Nappes of the Eastern Alps (Miladinova et al., 2022). We argue that the Veporic Unit represents direct continuation of the Eo-Alpine orogenic belt into the West Carpathians.

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Late Devonian–early Carboniferous granitic magmatism in the Bohemian Massif and Central Western Carpathians: what could explain the differences?

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Chronological, petrological, whole-rock geochemical and Sr–Nd isotopic data from the mid-Devonian to Tournaisian arc-related calc-alkaline magmatic rocks of Bohemian Massif (BM) and Central Western Carpathians (CWC) are comparable. The main difference comes in Visean, though. In the orogenic root of the BM (Moldanubian Zone), abundant Mg-rich, (ultra-)potassic intrusions are associated with HP–HT Grt–Ky felsic granulite bodies (Janoušek & Holub, 2007), while both rock types are noticeably lacking in the CWC.

This dichotomy reflects distinct palaeogeographic positions of these crustal segments in the Variscan orogenic belt, esp. the nature of the colliding plates. In the BM, the oceanic subduction passed into deep underplating/relamination of the attenuated Saxothuringian felsic crust, later converted to the HP–HT granulites (Schulmann et al., 2014). Soon thereafter, the contaminated lithospheric mantle produced Mg–K-rich magmas with a mixed crustal–mantle signature (Janoušek et al., 2022). In the CWC, the early oceanic slab break-off and ensuing asthenospheric upwelling (Broska et al., 2022) prevented the downgoing continental slab from reaching the mantle depths and contaminating the lithospheric mantle. This hindered the generation of Mg–K-rich mafic rocks in the CWC that are common in the more westerly parts of the European Variscan orogen, from Iberia to the Bohemian Massif.

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Weathering mineralogy and geochemistry of the polymetallic mineralization in Johan Hell mine, Maramureș, Romania, Eastern Carpathians

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The Johan Hell mine, located in Băiuț, Maramureș, Romania, within the Eastern Carpathians, is a part of the Breiner deposit, known for its Au-Ag mineralization and the presence of other elements like: Fe, Zn, Pb, Cu, As, and Sb. This mineralization is subject to extensive weathering, which contributes to the development of acid mine drainage (AMD). Consequently, a diverse assemblage of supergene minerals has formed in the mine. These minerals were analyzed using Powder X-ray Diffraction (PXRD), revealing a total of 23 distinct secondary mineral phases (SMP). Additionally, ICP-MS analysis was conducted on selected probes.

The most abundant SMP within the mine are Fe and Mg sulfates, including minerals from the halotrichite group, as well as rozenite, starkeyite, melanterite, hexahydrite, and the epsomite group. Notably, minerals from the voltaite group and römerite were also identified. These minerals are of particular interest due to their ability to sequester toxic elements such as Zn, As, Hg, Pb, Cd, Cu and Ta. Additionally, rare mineral phases such as paracoquimbite and lausenite were discovered.

Manganese is the most abundant trace element in the examined mine, occurring across all the SMP. Zinc ranks second in terms of prevalence and is detected across all SMP. Copper is predominantly associated with halotrichite (7000 ppm) and römerite (2000 ppm). Arsenic substitution has been observed in several minerals, including römerite (3700 ppm), voltaite (2800 ppm), copiapite (up to 1200 ppm), and halotrichite (up to 2050 ppm). Cobalt is primarily concentrated in voltaite, reaching levels of 310 ppm.

The low pH, along with the dry and hot climate inside the mine, creates favorable conditions for the crystallization of halotrichite. Initially, there was an abundance of water in the mine, but over time, the conditions shifted to a drier environment in which halotrichite remains stable. The evolving conditions promote the crystallization of a variety of SMP, which can generally be described by the following sequence: melanterite > rozenite > szomolnokite > copiapite > coquimbite > rhomboclase > halotrichite.

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High-grade metamorphism recorded by leucogranite in Ljusdal lithotectonic unit, Svecokarelian orogen: pressure-temperature constraints

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Ljusdal lithotectonic unit of the 2.0-1.8 Ga Svecokarelian orogen in central Sweden is dominated by the 1.87–1.84 Ga Ljusdal batholith with folded inliers of metamorphosed (often migmatitic) siliciclastic metasupracrustal rocks. Leucogranites are found in proximity to paragneisses and occur intermittently alongside gabbro intrusions. Peak metamorphism was reached at two separate events, but despite previous research efforts, the metamorphic characteristics remain a subject of ongoing debate. This study seeks to estimate the pressure-temperature (P-T) conditions during peak metamorphism through investigating mineral assemblages in leucogranite from the Sörfjärden area and thermodynamic modelling.

The Sörfjärden leucogranite is composed of K-feldspar, plagioclase, garnet, quartz, biotite, sillimanite, Fe-Zn-rich spinel, and ±cordierite with monazite, zircon, and rutile as accessory phases. Feldspar is represented both by perthite and antiperthite. Ternary-feldspar thermometry indicated crystallization temperatures of ~750ºC. Preliminary thermodynamic modelling indicated peak pressure-temperature conditions of 2.0–2.4 kbar and 740–770ºC, defined by the peak mineral assemblage garnet ($Alm_{78-81}Prp_{16-17}Grs_{0-3}Sps_{0-3}$), plagioclase, quartz, sillimanite, and spinel. The newly discovered green hercynite-gahnite spinel (X_{Fe}=0.61–0.67, X_{Zn}=0.22–0.29) is texturally associated with perthitic K-feldspar ($Or_{92}Ab_8$). The symplectitic textures on biotite and K-feldspar are interpreted as representing the second stage of migmatization.

The leucogranite likely formed during the first migmatization event (M1), which coincided with the formation of migmatites at ca. 1.86 Ga, and was subsequently metamorphosed and partially melted during the second migmatization event (M2) around 1.83–1.82 Ga (Högdahl et al., 2008; Högdahl & Bergman, 2020). This study provides important P-T constraints on the tectonic evolution in the Swedish segment of the Svecokarelian orogen.

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Monazite in-situ dating - thermometry - crystal chemistry: Three difficult relationships exemplified by orthogneisses from the Khanom Core Complex (Thailand)

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Monazite forms one of the cornerstones of petrochronological research. It offers the possibility of extracting in-situ age information down to ca. 2 µm spatial resolution and combining this with high-resolution crystal chemical data. Significantly, this can be done directly in a polished section or rock slab thus retaining textural relationships which are important to most reliably establish a rocks P-T-t-d-X evolution. Because of the plethora of known monazite related petrological processes in meta-(and semi-)pelitic rocks and amphibolites, petrochronological interpretations in such lithologies sometime are strongly ambiguous. On the other hand, monazite petrology in (meta-)granitic rocks is thought to be comparable simple, thus potentially delivering more reliable petrochronological results.

In order to test this hypothesis, we compare age spectra and chemical evolution of monazite related to the metamorphism of two Indosinian granitic orthogneisses from the Khanom Core Complex (S Thailand).

The unexpected outcome of our study is, that although both orthogneisses have the same whole rock composition and have experienced the same post-intrusive tectono-thermal evolution, monazite in the two samples shows completely different mineral chemical and geochronological response to the common overprinting events.

We document the partial to complete decoupling of in-situ U-Th-Pb ages, of monazite-xenotime equilibrium temperatures, and of the REE-Y versus U+Th+Si+Ca systematics in monazite. Also, texturally the monazite in the two samples show different behavior. While in one sample monazite is strongly resorbed, possibly by anatectic break-down, in the other sample no such resorption is found.

We address the sensitivity of the different mineral chemical components (REE+Y, U+Th+Si+Ca) to temperature, to re-equilibration, and to dissolution-precipitation processes. We suggest and show possible solutions of reconciling the data to extract petrochronologically useful information from the investigated granitic orthogneisses. One important aspect of our study thus is that only a complete integration of petrochronological data from multiple samples allows for a geologically unambiguous interpretation.

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The Cenerian Orogeny in the Western Carpathians - Indications from the Branisko Mts.

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The Cenerian Orogeny was defined as the early Paleozoic (490–440 Ma) metamorphic/magmatic events, which culminated in the Ordovician, due to recycling of continental crust in the cratonized subduction-accretion complexes (SACs). Commonly, the basement areas in the Alps formed by this orogeny are called as the "*Altkristallin*" and consist of the paragneisses, migmatites, orthogneisses, and banded amphibolites.

Similar crystalline basement, resembling the "*Altkristallin*", was identified in the Branisko Mts. (BM), the Tatric Unit of the Central Western Carpathians). The BM crystalline core is built by the so-called Patria complex consisting of Variscan magmatic rocks, including a biotite (± muscovite-biotite) granite to granodiorite (S-type) and a biotite granodiorite to tonalite (I-type), amphibolites, para- and ortho-gneisses often migmatized. Amphibolite rocks show variegated banded association dominated by presence of a medium to coarse-grained garnet-free hornblende-rich amphibolite accompanied by garnet amphibolite, locally with presence of eclogite boudins, and with pale plagioclase, quartz-rich bands. However, intimate relations between amphibolites and biotite-amphibole (tonalitic) gneisses within the Patria complex largely bear a resemblance to modern "*Greenstone belt*", and this gneissic – amphibolitic complex shows massive anatectic overprint/migmatisation. Besides the study of granitic rocks and their dating, special attention was paid to tonalitic gneisses in the BM.

The 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 respectively, indicating proto-magmatic age. The first possible 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.

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The Upper vs. Lower Unit of the Western Tatra Mts.: Lithology & Provenance

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Inverted metamorphic zonation in the Western Tatra Mts. (WTM) is one of the long-standing conundrums of Carpathian geology. The kinematic indicators suggest a complicated polyphase Variscan and Alpine deformation under ductile & brittle conditions with currently observable superposition of the Upper Unit (UU) over the Lower Unit (LU). On the basis of systematic field/structural research and detailed thermobarometry, a model of Variscan thrusting of the high-grade rocks (paragneiss, orthogneiss, migmatite, amphibolite, eclogite) in the hangingwall (UU) over the lower grade rocks (micaschists, meta-sandstone) in the footwall (LU) has been introduced in the WTM. Uplift and cooling took place between ca. 330–312 Ma, as recorded by Ar–Ar dating of biotite in metapelitic gneiss or biotite in the granitic rocks. However, recent Lu–Hf and Sm–Nd WR–garnet ages for eclogite (HP) of 354.5 ±1.2 Ma and garnet-bearing metapelitic gneisses (MP/HT) of ~346 Ma indicate continuous return of deep crustal material along the subduction channel from the maximal syn-collisional burial. This process was associated with the subsequent crustal extension.

Lithological variability of these two superimposed units was studied by means of the WR geochemistry, Sr + Nd isotopic composition in addition to U–Pb dating and Hf isotopic analysis of detrital zircons. However, considering that the LU is free from any meta-igneous products (amphibolite, orthogneiss etc.), the metasediments of both units share common characteristics. Their WR chemical compositions indicate a provenance from a passive margin or mature continental arc, $^{87}Sr/^{86}Sr_{(t)}$ = 0.712–0.725; $\varepsilon Nd_{(t)}$ = –4.5~ –11.1; $T_{(DM2)}$ = 1.6–2.5 Ga; the U–Pb data yielded comparable age spectra with dominant Ediacaran age peaks at ca. 600 and 590 Ma, a subordinate Tonian–Stenian cluster at ca. 1.10–0.65 Ga, limited Mesoproterozoic and/or Paleoproterozoic data and a few Archean ages; wide range of $\varepsilon Hf_{(t)}$ = –20~ +10 corresponds to two-stage Hf model ages $T_{(DM2)}$ of 2.5–1.1 Ga. Importantly, these common characteristics and/or similarities in the detrital zircon populations rule out the presence of a real suture zone between the LU and UU. However, the available data seem to rather indicate contrasting Variscan orogenic crustal levels originally formed within a single crustal domain.

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Polymetamorphic evolution of the eclogite hosting augen gneiss from the Richarddalen Complex, Svalbard

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High-pressure (HP) metamorphic Richarddalen Complex cropping out on NW Svalbard is composed of eclogites hosted by felsic rocks. Pressure-temperature (P-T) estimates for the eclogite yield peak metamorphic conditions of 1.9-2.5 GPa and 720-740°C followed by exhumation at ~1.2 GPa and 650°C (Elvevold et al., 2014). The age of the protolith of ca. 965 Ma for the host-rocks have been reported by several authors using U-Pb zircon dating. The recent works constrained the age of the HP event at ca. 495 Ma (U-Pb zircon, McClelland personal communication), and exhumation at ca. 440 Ma (Mazur et al., 2022). Here, we study eclogite hosting augen gneiss using trace elements thermometry and monazite dating.

Augen gneiss contains mineral assemblages formed during two metamorphic events. M1 represents the high-temperature (HT) conditions and consists of K-feldspar-I, plagioclase, garnet-I and quartz. Garnet-I forms up to 2 cm large porphyroblasts locally showing embayed grain boundaries. Its chemistry is homogenous ($Alm_{73}Pyr_{22}Grs_{3}Sps_{2}$). M2 assemblage comprises garnet-II, zoisite, rutile and quartz. Garnet-II forms coronas composed of euhedral, small (<100µm) grains growing around garnet-I as well as around clusters composed of biotite-chlorite-zoisite (possible cordierite pseudomorphs). Its chemistry varies from $Alm_{57}Pyr_{22}Grs_{20}Sps_{1}$ in the core to $Alm_{50}Grs_{33}Pyr_{17}Sps_{0}$ in the rim. M3 assemblage formed under lower grade conditions consists of chlorite, titanite and K-feldspar-II (i.e. likely breakdown products of biotite and/or phengite). Preliminary results of thermobarometry based on the inclusions within garnet-II confirm the P-T results of Elvevold et al. (2014) and support the HP origin of M2 assemblage. Th-U-total Pb dating of monazite from augen gneiss yields 956 ±7 Ma (n =20, MSWD =1.77). The age of monazite together with petrological observations suggests that the studied rocks experienced Tonian HT metamorphism.

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Detrital zircon Pb-Pb dating of the Polesie Formation – provenance and maximum deposition age of the oldest sediments at the western slope of the East European Craton (Orsha-Volyn rift, SE Poland)

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The Orsha-Volyn rift extends NE-SW, from the interior of the East European Craton (EEC) to the western margin of the EEC. The basin is filled mainly with continental reddish to variegated sandstone and mudstone of the Polesie Fm., the thickness of which reaches ca. 1000 m, being the oldest non-metamorphosed sedimentary cover of the western EEC. It contains no fossils, thus its stratigraphic age is ambiguous. Detrital zircon ages (SHRIMP) were investigated for sandstone from two core samples (well Kaplonosy IG 1, depth ~1875 m; 84 and 82 analytical points) to assess the timing of its deposition. The obtained data were confronted with the results (n = 86) of similar studies performed further east in Belarus and Ukraine (Shumlyanskyy et al., 2023, and references therein). The ages of the youngest zircons cluster at 1060 Ma to 1073 Ma. The youngest dated grain yielded Pb-Pb age of 1044 Ma, while the next three formed a group with a mean age of 1079 Ma, accepted as the maximum deposition age of the middle part of the Polissya Group in Ukraine. In Poland, following the vast stratigraphic gap, the Polesie Fm. was unconformably covered with the upper Ediacaran clastic sediments with tuffs and lava flows, providing the oldest age of ca. 580–570 Ma (Krzemińska et al., 2022). Moreover, the analysed samples contain a population of zircons yielding Pb-Pb ages of ca. 1290–1050 Ma, which is interpreted here as derived from the Grenville orogen, in the Neoproterozoic riming the EEC from the west. Another cluster of zircons yields Pb-Pb ages in a range of 1560–1450 Ma, typical of anorogenic within plate magmatic batholiths, common in the direct vicinity of the NW margin of the Orsha-Volyn rift. The remaining zircons (ages ca. 1850–1750 Ma) represent the Svecofennian basement of the northern flank of the basin. The age of the Polesie Fm. remains poorly constrained, but we conclude that its maximum depositional age is early Neoproterozoic (< 1060 Ma).

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Evolution of lower crust and upper mantle beneath Southern Uplands and Midland Valley Terranes (S Scotland): constraints from ultramafic cumulitic xenoliths in alkaline mafic lavas

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The lithosphere beneath Scotland was significantly affected by Permo-Carboniferous alkaline volcanism, which brought to the surface a wide suite of ultramafic xenoliths. This study investigates ultramafic cumulates, including clinopyroxenites, (±Ol) websterites and wehrlites with variable textures. Those rocks carry information on the structure and evolution of the regional mid-lithosphere before and during the time of volcanism.

The temperature and pressure of clinopyroxene crystallization vary in narrow ranges: 1160-1240ºC and 0.85-1.26 GPa (rarely up to 1.65 GPa), respectively. As the Moho is located at ~1 GPa, the cumulates crystallized in the lower crust and upper mantle.

Clinopyroxenites ($Mg\#_{Cpx}$ 0.74-0.78) and wehrlites ($Mg\#_{Cpx}$ 0.76-0.83; Fo_{Ol} 76-82) are characterized by adcumulate texture and exhibit a negative correlation between Mg# and Al content in Cpx, accompanied by decreasing Fo content in Ol. These observations suggest that wehrlites and clinopyroxenites are products of fractional crystallization of an alkali mafic melt, with wehrlite produced at the initial stages of crystallization and clinopyroxenites formed at more advanced stages. The chemical composition of minerals forming (±Ol) websterites and Opx-clinopyroxenites differentiates them into two groups: a high Mg# group ($Mg\#_{Cpx}$ 0.79-0.82; $Mg\#_{Opx}$ 0.80-0.81; Fo_{Ol} 79-80) and a low Mg# group ($Mg\#_{Cpx}$ 0.71-0.75; $Mg\#_{Opx}$ 0.72-0.75; Fo_{Ol} 69-71). The high Mg# group with adcumulate texture may represent an early stage of mafic magma fractionation and crystallization of Opx+Cpx±Ol. The low Mg# adcumulates represent a later stage of magma fractionation, dominated by pyroxene formation at high Cpx/Opx ratio. The high Mg# websterites having meso- to orthocumulate texture with Opx grains poikilitically enclosed by Cpx were formed due to the introduction of Cpx to the older Opx-bearing rocks. The origin of the studied websterites suite is not straightforward, and it is essential to consider the alternative possibility that the websterites may be related to tholeiitic melts.

Our studies suggest complex and multistep evolution of Permo-Carboniferous melts beneath Scotland comprising fractional crystallization and reaction with ultramafic rocks.

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Hydrothermal alteration of andesite rocks from the Szczawnica – Krościenko area, Western Carpathians, Poland. Cases from Ciżowa Hill and Pałkowski Stream intrusions

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Neogene intrusions of andesitic igneous rocks occur on the contact of the Magura Unit of Outer Carpathians and the Pieniny Klippen Belt (Birkenmajer, 2003 and references therein). These rocks are subject to weak-to-moderate hydrothermal alteration processes such as propilitization, biotitization, carbonatization, zeolitization, chloritization, and argillitization. These processes are more intense in the eastern part of the andesite area (Gajda, 1958; Birkenmajer et al., 2004).

Intensive processes of carbonatization, argillitization and zeolitization have been found in the intrusion from Ciżowa Hill in Szczawnica. They caused granular disintegration of the rock in part of the analyzed intrusion,. Amphibole crystals were especially susceptible. They underwent the processes of chloritization: the titanium has been extracted from the structure of the decomposed amphibole andused to form titanite. The other process, leukoxenization of titanite, led to the formation of Ti oxides. The chloritized amphiboles underwent further transformations with the forming of kaolinite/dickite and quartz.

Similarly intense hydrothermal processes can be observed in the Pałkowski Stream intrusion. Strong propilization led to the formation of chlorite, epidote (also REE-epidote), and carbonates (calcite, ankerite). Propilization is overprinted by potassic metasomatism forming biotite, K-feldspar, and quartz. Ti-magnetite and ilmenite were subjected to particularly intense alterations. Magnetite was almost completely replaced firstly by titanite and biotite, as well as later by chlorite, epidote and sulfides (pyrite, pyrrhotite, chalcopyrite). Ilmenite was also replaced by pyrophanite. The hydrothermal alteration associated with Cu±Ag±Mo porphyry deposits can be observed within this intrusion as well as in surrounding rocks. This puts this intrusion in contrast to others that do not have hydrothermal alterations and may indicate its different evolution.

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The REE-minerals in the contact zone of Neogene andesites in the Pieniny Klippen Belt, Western Carpathians

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Small-volume hypabyssal intrusions of Neogene andesites are spatially related to the Pieniny Klippen Belt (PKB; Birkenmajer, 2003 and references therein). The andesitic rocks are located north of the PKB line within the Magura unit, which is mainly composed of flysch type sediments (sandstones, shales, marls). The interaction of the small magmatic bodies with the surrounding sedimentary setting have resulted in poorly developed contact alteration halos around the intrusions. In these zones, the following minerals have been identified as the result of thermal and hydrothermal alteration: chlorite, epidote, calcite, quartz, garnet, pyrrhotite, wollastonite, diopside, calcite, sanidine (Szeliga & Michalik, 2002 and references therein).

New detailed studies have provided data on minerals formed by contact metamorphism and hydrothermal activity. Phases containing REEs and thorium have been found: mainly epidote and F-carbonates. Elevated REE contents in the epidote are observed in the external parts of the crystals. Based on EMPA analysis the allanite may contain up to 22.27 wt. % of REE_2O_3 (Ce_2O_3 up to 12.57 wt. %). F-carbonates are texturally younger than the epidote group minerals and contain of CaO - 12.09 wt. %, REE_2O_3 - 48.87 wt. %. (where Ce:La:Nd - 2:1:0.5). High content of cerium suggests the presence of parisite-(Ce). Thorium minerals form small crystals as intergrowths with apatite, epidote-allanite and chlorite. Th content is up to 49 wt. %, U content up to 14.27 wt. % and Si content up to 6.81 wt. %.

The aforementioned minerals were found in close contact with the intrusion (20 - 30 cm), suggesting high temperature conditions. However, the co-occurrence of REE minerals, especially fluorocarbonates and oxides with chlorites, indicates lower temperatures in terms of hydrothermal activity. The presence of fluorine indicates a significant halide contribution to metal transport.

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Chemical and phase analyses of Mikoszewo micrometeorite collection

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Micrometeorites (MMs) are extraterrestrial particles smaller than 2 mm that reach planetary surfaces, providing valuable material for research. This study analyzes extraterrestrial spherules collected from the roof of a primary school in Mikoszewo, Poland. Out of ~10kg of material after sieving, flotation, and magnetic separation 116g of material <1mm size was left for handpicking.

A total of 36 MMs were identified, primarily in the 315–88 µm fraction (n=33), with 28 grains analyzed using SEM-EDS and all confirmed by Raman spectrometry. Among the 36 grains, 12 were barred olivine (BO) type, 8 porphyritic olivine (PO), 11 cryptocrystalline (CC), 2 scoriaceous (Sc), with single grains of vitreous (V), and glass (G) types. BO-type MMs exhibited a consistent silicate composition with Mg (8–18%), Fe (20–43%), Si (11–18%), and O (30–41%), along with ~0.75% nickel. PO particles displayed diverse Fe content (12–40%) and varying Mg levels (2-8%), (11-13%) and (17-19%), while CC spherules showed Fe (8–19%), Mg (11–16%), O (39–48%), and Si (19–24%). The Raman spectra of 10 MMs showed bands at 390 cm^{-1}, 660–670 cm^{-1} (magnetite), 820 cm^{-1}, 850 cm^{-1} (forsteritic olivine), with bands indicating organic matter at c. 1350 cm^{-1} and 1600 cm^{-1} up to 30µm below the surface. Additionally, one PO micrometeorite also revealed Raman shifts at 390 cm^{-1}, 660 cm^{-1}, and 1010 cm^{-1}, identified as pyroxene.

Analysis of the micrometeorites from the Mikoszewo collection showed that size of the micrometeorites show similar maxima (150 and 210 µm) to those observed in other present day urban and Antarctic collections, with barred olivine (BO) MMs having a different size maximum (180 µm) compared to the other grains. More melted MMs generally contain less iron on their surface, likely due to evaporation during high-temperature atmospheric entry. Analysis of aerodynamic micrometeorites revealed a progressive shift of the bands corresponding to olivine, which suggests that the crystallization of the micrometeorite surface in the atmosphere occurs from the front towards the more fayalitic composition of olivine in the aerodynamic tail.

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Accessory minerals in the Variscan granitoids of Nízke Tatry Mts. (Tatric Unit, Western Carpathians, Slovakia) as indicators of magmatic-hydrothermal ore-forming processes

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The Nízke Tatry pluton (NTP) is composite early-middle Carboniferous intrusion varying from gabbro-diorite, through the most voluminous hybrid tonalities and granodiorites, to leucogranites. The heterogeneity of the NTP expresses prolonged, polygenetic magmatism and complex differentiation path of the magmas in arc- to postcollisional setting. The NTP hosts exceptionally rich and diversified ore mineralization. The highest temperature, Variscan stages include Mo, W, Au-As, Sb-Zn-Pb associations which origin in frame of the regional geodynamic and magmatic-metamorphic processes is yet ambiguous.

Accessory minerals (AM) are excellent tools in tracking magmatic-hydrothermal ore-forming processes. High in S igneous apatite and S±Sr-rich secondary monazite in the granodiorite and its dioritic enclaves evince high SO_4^{2}±CO^{2-} and fO_2 in parental melts and associated fluids and resemble polymetallic porphyries and epithermal Au-Cu deposits. Sulphur was likely carried by mafic melt (S content in apatite corresponds to up to 0.1 wt. % S in melt) and complex magma-magma interaction affected local gradients of the redox state and volatile budget which are crucial parameters controlling metals mobility and enrichment. On the other hand, minor leucocratic granite bodies occurring close to ore-bearing areas contain multiple generations of U,Y+REE, P, Hf–rich and –poor zircon, apatite, xenotime, and F-rich monazite. The AM in leucogranites recorded interaction between the phenocrysts, highly differentiated melts and reactive, high-temperature fluids at magmatic-hydrothermal transition, which is essential phase for ore generation, and share features with fertile intrusions, in particular with rare-metal suites.

Overall, the multisource (upper to lower crust±litospheric mantle), long-lasting magmatism in the NTP controlled by slab-break off facilitates the ascent of fluids from the enriched mantle but also metal recycling via crustal anatexis, and consequently development of different ore associations. Following protracted evolution of magmas involving mixing at various crustal levels, accumulation and fractional crystallization influenced key chemical and physical parameters for fluids and metal speciation and enrichment. The AM in the granitoids provide insights into evolution of the magmas and fluids and their ore-forming potential and add an another dimension to the current metallogenetic models of the NTP and Western Carpathians.

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Mineral-melt and mineral-fluid interactions recorded in enigmatic mafic cumulates in NE Prins Karls Forland (Svalbard)

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Blocks of mafic (meta)cumulates (MCs) occur within the crustal-scale shear zone deforming polymetamorphosed metasedimentary complex of NE Prins Karls Forland island (SW Svalbard). The MCs fabrics vary from ideally preserved heterocumulate to cataclastic-protomylonitic, depending on the position of a certain body within the shear zone. The primary minerals are corroded laths of cumulus plagioclase (An_{61-48}) and ilmenite within poikilitic Ti-rich (3.5-4.5wt. %) Mg-pargasite–hastingsite (Amp1), partly replaced by late-stage Mg-hornblende (Amp2) and actinolite (Amp3). Only single relicts of clinopyroxene ($Wo_{47}En_{39}Fs_{14}$) are preserved within Amp1. The accessory minerals are: phlogopite, F-Cl-OH to F-OH-Cl apatite (Ap1), and zircon. The grade of the deformation is coupled with development of the secondary assemblage: Cl-rich (>2 wt. %) Fe-(K)-pargasite (Amp4), Cl-rich annite, chlorite, epidote, scapolite, titanite and low-Cl F-OH-apatite (Ap2). Chemically, the MCs partly resemble oceanic island gabbro, however their composition is equivocal: they are transitional between (calc)-alkaline and tholeiitic, high in Al_2O_3, MgO, FeOt, TiO_2 and Na_2O, V, Sc and LREE/HREE, but low in P_2O_5, Cr, Ni, Th, Zr and U. The alteration resulted in removal of Ti, Fe, and LIL and variable enrichment in Si, Ca, P, REE's and HFSE.

Assessment of mineral composition and geothermobarometry reveals the complexity of the magmatic and metasomatic history of the MCs. Plagioclase and clinopyroxene crystallised from the alkali and H_2O-poor, but relatively differentiated tholeiitic melt at P~6-8kbar, T~1200-1050ºC, and were followed by post-cumulus ilmenite and Ap1. The extensive reaction and re-equilibration of the crystal mush with percolating alkali-, halogen- and H_2O-rich (4.5-6 wt. %) granodioritic-tonalitic melt resulted in formation of poikilitic Amp1 at ~950ºC, P~3.5-4.5 kbar, followed by phlogopite and Amp2 (T~750ºC P~2.9-2 kbar) and sub-solidus Amp3. The MCs are spatially associated with Kiruna-type ores. The unusually low content of P, REEs, U and Th in the MCs could be linked with their partioning to the latest-stage fluid-rich Fe-P-REE ore melt. The secondary assemblage in MC reflects circulation of the oxidizing, Fe-Na-Ca-Cl-rich (over 50 wt. % salinity) fluids released from MCs, ore bodies, and hosting metasediments during deformation and metamorphism. Despite some similarities shared with the Ediacaran magmatism in SW Spitsbergen, the origin of the MC still the question mark.

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Influence of subduction on the lithospheric mantle - preliminary studies on peridotitic xenoliths from NW Turkiye (Thrace region)

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A Miocene mafic lavas from NW Turkiye carry a wide suite of peridotitic xenoliths. The xenoliths sample lithospheric mantle which was affected during the closure of Neothethys. In this study we report preliminary results on peridotitc xenoliths from two localities in the Thrace region to unravel the evolution of the lithospheric mantle affected by subduction zones.

The peridotites have normative composition of harzburgite and lherzolite. The Mg# varies from 88.4 to 91.1 and is negatively correlated with contents of Al_2O_3 (0.32–3.49 wt. %) and Ni (1900–2600 ppm) as well as with normative content of clinopyroxene. Harzburgites have typically subchondritic contents of REE, and LREE are slightly enriched. Strontium anomaly in harzburgites varies from positive to negative, while Eu shows slightly negative anomalies. Lherzolites usually have flat REE pattern with positive Sr and slightly negative Eu anomalies. Content of Cu for both harzburgites(15.2–38.9 ppm) and lherzolites (4.2–21.7 ppm) is negatively correlated with Mg# (R^2 =0.52). The same negative trend is also observed for Sc (R^2 =0.80) and Au (R^2 =0.46). In each lithology, single samples are LREE-depleted and show enrichment only in Nb and Rb.

The negative correlation between Mg# and the contents of Al_2O_3, and chalcophile metals, and its relation with normative composition in the studied set of samples, points to significant mantle depletion. This process was likely multi-stage and occurred at pressures below 1 GPa. The influence of subduction-related melts on the peridotites is not well established, as they do not show significant depletion in High Field Strength Elements expected in those geological settings. On the other hand, the peridotites are slightly enriched in Fluid Mobile Elements (e.g. Sr, LREE) pointing out that minor metasomatic enrichment must have taken place. Despite this, we did not observe the mobilization of chalcophile metals. Furthermore, in the LREE-depleted peridotites, the influence of metasomatism is barely visible. Therefore we claim, that the major process affecting the evolution of the lithospheric mantle in NW Turkiye was melt-depletion, whereas the metasomatic processes had a rather limited effect.

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Common origin, separate fates – subduction influence controlling chemical evolution of Puke and Kukes massifs, Mirdita Ophiolite

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Different lithological and geochemical evolution characterize ultramafic massifs in Mirdita Ophiolite (N Albania). Massifs located in the east are dominantly harzburgitic with refractory chemical composition, whereas those in the west are plagioclase lherzolites rich in Al and Ti. Those differences are commonly referred to the evolution of the massifs in different tectonic settings, i.e. SSZ for the eastern and MOR for the western massifs (Dilek et al., 2008). However, harzburgites are also present in western massifs and two of them – Puke and Krrabi – were recognized as fossil Oceanic Core Complexes (e.g., Nicolas et al., 1999).

In this study, we compared the textural features and chemical composition of harzburgites from Puke and Kukes massifs, the latter from eastern massifs, to verify if differences, related to evolution in different environments, exist. Sample set was restricted to harzburgites as they are the only primary lithologies in both massifs. The dominant texture in both massifs is high-T porphyroclastic, with scarce clinopyroxene (Cpx) spatially associated with orthopyroxene (Opx). The major element composition of minerals in both massifs is comparable, e.g. olivine has Fo= 90.4-91.1 in Puke and 90-91.2 in Kukes, Cpx Mg#'s are 92.5-95 and 93-95 respectively, Opx Mg#=90.5-91.2 in Puke and 90.5-91.5 in Kukes, while spinel has Mg#=47-65 vs. 52-65 and Cr#=40-61 vs. 46-62, respectively. In Puke, Lu content in Cpx is relatively low (Lu_N=0.5-1.1), but split into two trends: heavily and moderately depleted in LREE ($(La/Lu)_N$~0.001 and ~0.01, respectively). In Kukes, Cpx is poorer in Lu (Lu_N =0.4-0.6) and also depleted in LREE, however showing significant fractionation ($(La/Lu)_N$ =0.002-0.030).

The dominant texture and chemical composition of minerals in both massifs point to similar degrees of extensive partial melting of harzburgites in spinel facies. However, scenarios of their later evolution differ. Puke massif was deformed in melt-assisted conditions, forming fertile plagioclase-bearing mylonites; some harzburgites may also be impregnated with magmatic Cpx. In Kukes, the melting episode was followed by later refertilization, leading to increased LREE abundance in Cpx, possibly related to SSZ fluid percolation. These evolution paths may be related to different distances to the subduction zone.

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New ^{147}Sm/^{144}Nd isotopic data and U-Pb zircon ages of the granitoid rocks of the Vepor pluton in the Fabova hoľa area (Vepor Unit, Inner Western Carpathians, Slovakia)

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The Fabova hoľa Massif and its surroundings belong to the Veporic Unit (Inner Western Carpathians, Slovakia). It consists of medium- to high-grade metamorphic rocks intruded by Variscan granitoids, covered by Permian-Triassic sedimentary rocks (Plašienka et al., 1997). The basement and cover rocks underwent Alpine (Cretaceous) tectono-metamorphic overprinting in higher greenschist facies medium pressure conditions (Putiš, 1994).

Three lithological types of the Variscan granitoids have been described in the Fabova hoľa area: medium- to coarse-grained, (meta)granodiorites to (meta)tonalites of the Sihla-type and biotite (meta)granites to (meta)granodiorites of the Vepor and Ipeľ types. Negative values of the initial εNd_t are higher for the granitoid rocks of the Vepor and Ipeľ types (-2.7 to -2.2) and lower for the granitoids of the Sihla type (-1.2). The U-Pb isotope dating of zircons gave 357 ±1.3 Ma for the Vepor granitoids and 345 ±2.9 Ma and 359 ±1.5 Ma for the Ipeľ granitoids. The geochronological data of 355 ±1.9 Ma was obtained by in-situ U–Pb chemical dating of monazite-(Ce) from granitoids of the Vepor and Ipeľ types.

The preliminary results indicate an I-type isotopic signature for the less differentiated Sihla type and a hybrid S-/I-type signature for the Vepor and Ipeľ types. The Visean age of the Ipeľ type pointed out it is probably late and more evolved intrusive part in the Vepor pluton than more widespread Vepor type. The formation of studied Tournaisian and Visean granitoids may be related to Variscan (post)-collisional extension and are consistent with an anatectic event triggered by asthenospheric upwelling and heat input from the mantle after slab break-off in the Western Carpathians (e.g., Broska et al., 2022).

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Phase transitions of anhydrous sulfate with strontium substitution

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During mining operations at the Bochnia Salt Mine, now a UNESCO World Heritage Site, it was observed that freshwater infiltrations into the anhydrite layers surrounding the deposit leads to the hydration of anhydrite ($CaSO_4$) into gypsum ($CaSO_4 \cdot 2H_2O$). Since host anhydrite is partially Sr-substituted (0.1-0.2%, Puławska et al., 2021), the mineral transformation mechanisms, along with the release of strontium, remain not fully understood. In this research laboratory model experiments were designed to aid the study of the phenomenon.

Analogs of anhydrite-Sr with varying Sr content were synthesized and transformed to gypsum under controlled laboratory condition through hydration in solutions that simulate the infiltration of freshwater into the deposit. Five syntheses were performed, including anhydrite, Sr-substituted anhydrite (containing 0.1%, 1%, and 2% Sr), and celestine ($SrSO_4$). Each synthesis was carried out over three hours at a constant temperature of 120°C (Kamarou et al., 2021).

The next phase of the project involved hydrating synthetic sulfate samples for 70 days in 500 mL of redistilled water with 2.5 g of solid (1:10 solution to solid ratio), with sampling every 1-2 weeks. Phase analysis of solids was conducted using powder X-ray diffraction (PXRD) and scanning electron microscopy (SEM), while chemical composition was analyzed via inductively coupled plasma optical emission spectroscopy (ICP-OES).

The synthesis was successful in obtaining Sr-doped anhydrite. The maximum Sr substitution in anhydrite was experimentally determined at 1-2 wt. %. Phase transformation occurred at the earliest at 21 days, in pure and 0.1% anhydrite, forming bassanite ($CaSO_4 \cdot 0.5H_2O$) and then gypsum. Pure celestine has not been transformed to any other phase during the hydration process. Strontium is released to solution. Model hydration experiments reflect natural processes that occur in Bochnia Salt Mine. Further research is needed to better understand the fate and influence of Sr on minerals in salt deposits.

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Chevkinite group minerals from the Ełk Syenite Massif – their alterations and significance for secondary REE mineralization

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The Ełk Massif, with an area of about 400 km^2, is one of the largest massifs belonging to the Lower Carboniferous igneous province formed on the western slope of the East European Craton (Poprawa et al., 2024). The massif is mainly made up of different varieties of syenite, containing varying amounts of minor nepheline, cancrinite, sodalite, aegirine, arfvedsonite and quartz. In the R1-R2 (De La Roche) classification diagram, the systematic position of the rocks range from nepheline syenite to monzogabbro. The massif is a polycyclic intrusion and its present ring-shaped form is the result of four stages of syenite melt intrusion. The rocks of older magmatic stages are locally intensively metasomatically and/or hydrothermally altered.

Chevkinite-group minerals (CGM) were identified in all syenite varieties of the Ełk Massif (Nejbert et al., 2020). The CGM commonly form aggregates up to 500 μm in length, elongated along the boundaries between alkali feldspars. The CGM grains with a tabular and common euhedral habit very often occur in association with Fe-Ti oxides, aegirine and pyrochlore. Small-sized CGM inclusions were also observed in the main rock-forming minerals. Zonal or patchy variability in chemical composition, clearly visible on BSE images, was commonly observed in all CGM grains. The CGM are exclusively represented by chevkinite-(Ce) with Ti dominating the C site. The major substituents are Mn, Nb, Th and Zr. The average formula calculated from more than eighty analyses is: $[(Ce_{1.81}La_{1.38}Nd_{0.33}Ca_{0.29}Th_{0.07})_{3.9}Fe^{2+}(Ti_{0.84}Fe^{2+}_{0.66}Mn_{0.41}Nb_{0.05}Zr_{0.05})_{2.0}Ti_2(Si_{2.0}O_7)_2O_8]$.

The CGM from older synites of the Ełk Massif are strongly altered. In some cases, these minerals were replaced completely by pseudomorphs consisting of allanite, epidote, titanite, Ca-Mg and REE carbonates. Chevkinite is usually underestimated in numerous igneous rocks (Nejbert et al. 2020). Its low stability in environments with high H_2O activity may explain the secondary economic concentrations of REE in sedimentary carbonates occurring in the surroundings of igneous intrusions (e.g., the Bayan Obo deposit in China).

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Metamorphic evolution of coesite-bearing eclogites from the Złote Mts. (Orlica-Śnieżnik Dome, NE Bohemian Massif)

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We studied eclogites coming from Bielice in the Orlica-Śnieżnik Dome (NE Bohemian Massif) and confirmed that they underwent ultra-high pressure (UHP) metamorphism, as shown by coesite inclusions in garnet and omphacite. The occurrence of coesite in this unit has been suggested earlier by several authors based on the observation of possible quartz pseudomorphs after coesite (e.g., Bakun-Czubarow, 1992). To decipher the metamorphic evolution of the samples we used phase equilibria modelling, conventional geothermobarometry, Zr-in-rutile thermometry and quartz-in-garnet elastic barometry.

Unlike other eclogites from the Orlica-Śnieżnik Dome, the Bielice eclogite lacks phengite in the peak pressure mineral assemblage. It comprises Grt + Omph + Rt + Ky + Coe. Combined results of thermodynamic modelling and Zr-in-rutile thermometry for inclusions in garnet yielded pressure of 3.05-3.2 GPa at temperature of 770-830°C. Conventional geothermobarometry results, based on Grt-Cpx thermometry coupled with barometer based on net-transfer reaction diopside + kyanite = grossular + pyrope + coesite, yielded slightly higher temperature of 840 ±40°C at pressure of 3.16 ±0.15 GPa. Quartz-in-garnet barometry results yield entrapment pressure of ~2.0 GPa at 840°C. This result can be interpreted either as the conditions of entrapment on the prograde path of metamorphism or as a result of relaxation of residual pressure due to some post-entrapment processes. As we do not observe any clear pattern in the distribution of quartz and coesite inclusions in garnet hosts, we believe that viscous relaxation of garnet at high temperature has more likely led to relaxation of the residual pressure recorded in quartz inclusions.

Moreover, we observe that the first decompression event preserved in the sample is marked by the appearance of amphibole grains developed along garnet grain boundaries. Based on their rather small volume (~ 5 vol. %) and their X_{Mg} = 82-86% we have determined that the first decompression event occurred at pressures of 2-2.1 GPa at 710-760°C.

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Cretaceous – Early Miocene palaeogeography of the Carpathians in Poland as derived from the first cycle and recycled detrital zircon provenance study

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Our project, dedicated to the provenance study of detrital zircons from the Carpathian flysch sediments, is subdivided into three phases. During the first phase, the Krosno and Menilite formations have been already studied, whereas the next two phases aims at focusing on the Mesozoic and Paleogene parts of the Outer Carpathian sedimentary sequences. To date, a total of 53 rocks of the Menilite and Krosno formations were used for detrital zircon provenance study. This set of samples comprise the Dukla, Silesian, and Skole structural units collected from various regions of the Polish Outer Western Carpathians. In the frame of the ongoing second phase, a set of 98 samples is the subject of research.

By the realization of this project, we aim at spatiotemporal reconstruction of the Carpathian's paleogeography, determining the sedimentary inputs into the Polish Outer Western Carpathians (Nawrocki et al., 2024). Furthermore, the disclosure of the sediment source regions may contribute to resolving conflicting arguments on the location of concealed terranes that formed during the Carboniferous Hercynian Orogeny. The research combining the sedimentology, petrography, zircon morphology, and SHRIMP-based U-Pb detrital zircon geochronology means that sediment recycling effects can be evaluated.

In the Menilite and Krosno formations the most frequent are mid-Variscan and Cadomian age zircons that were derived from the Variscan Internides underlying the studied basin, and from the Brunovistulia Terrane, respectively. The Sveconorwegian and Calymmian age zircons that likely constitute the Statherian recycled zircons of Baltica are abundant in the Menilite Formation, and are most probably derived from Lower Devonian sediments of the Małopolska Massif. The Oligocene basin of Menilite Formation was supplied in detrital material largely from the north where Meta-Carpathian Swell was elevated in the area of Małopolska Massif and Brunovistulia Terrane. During sedimentation of the Krosno Formation in early Miocene this source expired.

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Zircons Age Catalog (ZAC) for reconstructing provenance in the Outer Western Carpathians in Poland

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Zircon U-Pb isotope dating is by far the most powerful and widely used method to determine the ages of geological events providing insights into the spatiotemporal evolution of investigated regions. Given the zircon age distribution from the whole rock samples and sample sets collected from the considered structural units, we can recognize the changes in zircon provenance in time and space and determine the alimentation sources. Despite several zircon age databases (global, regional, and national) that have been constructed over the last decades (e.g., Puetz et al., 2024 and references therein), the region of the Carpathians and adjacent units did not constitute the particular focus. To mitigate this, a comprehensive catalog of both magmatic and detrital zircon ages that might have constituted the repository for the provenance reconstructions is needed. In the scheme of the project investigating the provenance of detrital zircons in sedimentary rocks of the Outer Western Carpathians, we envisaged the creation of such a database collecting zircon ages from structural units that might have constituted the sources for the sedimentation.

The current database comprises two primary Excel spreadsheets including >1,900 magmatic (one record per sample with the interpreted best age) and >39,000 detrital (single analytical spots) U-Pb zircon ages utilizing ~580 research publications. The usage of the Excel format is generally accessible to the entire research community, with the data easily exported to open format following the FAIR principles and other commonly used frameworks as well as it contains functionality that mimics a primary-key/foreign-key link in a relational database. The database includes full bibliographic descriptions of referenced publications that are stored in the dedicated folder, sampling locations with GPS coordinates, U-Pb ages, uncertainties, laboratory settings, and the authors' interpretation, among other variables. As data has been collected from published research, and then transferred into the catalogs, mistakes invariable happen along all steps of production chain. Therefore, data are validated using criteria that ensure each data field contains reasonable values. The work related to the creation of a database will be continued, providing valuable insights into a better understanding of the zircon provenance for Carpathian's foredeep basins.

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Pyroxenite dykes control sulfide segregation and the subcontinental lithospheric mantle metallogeny of Balmuccia peridotite massif

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The focused flows of mafic melts are common in the subcontinental lithospheric mantle. This phenomenon is recorded by the presence of pyroxenite dykes within mantle rocks and composition of pyroxenitic and metasomatized peridotitic xenoliths. Although they exert significant control on the upper mantle magmatic differentiation, their role in the metal transport and mantle refertilization remains poorly constrained. This is likely caused by the limited number of fresh upper mantle exposures containing primary ore mineralization and free of hydrothermal overprint. To investigate the sulfide segregation and related metallogeny, we sampled the Balmuccia peridotites (Ivrea-Verbano zone), which is well exposed and has well-established geological framework.

Here, through scrutiny of the pyroxenite dykes and their contacts with mantle peridotites, we provided insight into the sulfide and associated chalcophile metals (e.g., Cu and Ag) distributions. The Balmuccia mantle pyroxenites are rich in magmatic sulfides (from 0.43 to 13.42 vol. ‰; n=10) comprising pentlandite-pyrrhotite-chalcopyrite assemblages with respect to reference Balmuccia peridotites (0.12 ±0.03 vol. ‰; 1SD; n=3). The studied pyroxenite dykes contain up to 8 times more Cu (on average 217 ±62 ppm; 1SD; n=9) than the peridotites (27 ±20 ppm Cu; 1SD; n=22). Moreover, we reported high correlation values (R^2 =0.96) for Cu vs. Ag. Our *in-situ* measurement results show that each sulfide phase has distinct S and Fe isotopic within-grain values. For instance, pyrrhotite revealed consistent negative δ^{56}Fe values (–1.44 to –0.36‰), whereas the δ^{56}Fe values determined for chalcopyrite and pentlandite provided positive signatures (+0.13 to +0.99‰ and –0.33 to +1.45‰, respectively). We asserted that the isotopic differences among sulfides are controlled by the mass-dependent kinematic fractionation that follows the sulfide (re)crystallization under high-T subsolidus magmatic conditions.

The increased amount of sulfides and associated metals (Cu and Ag) in the studied mantle pyroxenites might have a widespread character in the subcontinental lithospheric mantle. Therefore, we estimated that from 11% to 41% of the Cu and from 10% to 37% of the Ag of the upper mantle inventory is accumulated within the mantle pyroxenites providing essential implications for the mantle metallogeny. This indicates that sulfide distribution heterogeneity should be addressed in further studies and accounted for in global metal budget calculations.

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The Mississippian Lublin-Baltic alkaline igneous province (SW slope of the East European Craton)

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Our study of boreholes, seismic survey, and magnetic data from the region between the Baltic Basin and the Lublin Basin indicates the existence of numerous buried intrusions and effusive rocks, most of them unnoticed so far, together with a few igneous alkaline plutonic complexes (Poprawa et al., 2024, and references therein). They have silica under and oversaturated characteristics and are derived from depleted mantle or lower crustal sources. The plutonic complexes developed during a few magmatic pulses at 352 ±3 Ma, 344 ±3 Ma, and 337 ±2 Ma, accompanied by hydrothermal phases, extensive phonolite-trachyte volcanic associations, and numerous subvolcanic microsyenites, dykes and veins series (Krzemińska et al., submitted). In the central part of the Baltic Basin, deep seismic data reveal the presence of large sills, extending at least 160 km (N-S), emplaced in the crystalline basement at depths of 7-18 km (Pasłęk-Polik Deep Sills). In the Lublin Basin, the same data disclose deep sills in the sedimentary cover at a depth of ca. 5.5-6.5 km, extending for ca. 50 km (Minkowice-Pliszczyn Sills). Both coincide with shallower, lower Carboniferous intrusions of the sub-seismic scale. In the central part of the offshore Baltic Basin, conventional 2D seismic data reveals the occurrence of a sill system developed in the lower part of the Silurian section, extending c. 150 km N-S (Gdańsk-Dalders Sill). All these igneous rocks occur in the coherent region and constitute a hitherto unrecognized Lublin-Baltic Mississippian Igneous Province (LBMIP; >120,000 km^2; Poprawa et al., 2024). Thermochronological data from the Polish Baltic Basin indicate the presence of a Mississippian positive thermal event, associated with the LBMIP. Denudation of the LBMIP is evidenced by the Carboniferous volcaniclastics of high thickness, developed in the adjacent basins. The alkaline magmatism activity was triggered by thermal anomaly and/or mantle decompression caused by stress field reorganization, induced by the Variscan continent-continent collision in its far foreland.

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Microstructural study of coesite to quartz transformation during retrograde metamorphism of ultra-high pressure rocks

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As one of the most abundant naturally occurring oxides, SiO_2 also constitutes an important component of the geological environment. It occurs as quartz in most of the rocks. However, its polymorph called coesite forms under ultra-high pressure (UHP) metamorphic conditions. Coesite represents a significant indicator of such extreme conditions typical for tectonically active zones. However, it is scarce in the exhumed rocks and often recrystallise back into quartz. The objective of this study was to investigate the microstructural changes of SiO_2-rich samples from the well-characterized Dora Maira white schists from the Western Alps. This work was carried out using microstructural observations, electron backscatter diffraction (EBSD), hot cathodoluminescence (CL) and scanning acoustic microscopy (SAM). The studied samples comprise mainly quartz, garnet and phengite. Quartz occurs in the matrix and as inclusions in garnet. Coesite is found as inclusions (up to 2 mm in diameter) within garnet and is typically surrounded by quartz. Our observations allow us to distinguish following three distinct microstructural stages of quartz which could have formed during retrograde metamorphism and phase transition from coesite. (1) The initial phase, PQ1, is the formation of the first generation of palisade quartz. Quartz forms a thin rim composed of narrow (0.005 to 0.1 mm wide) and perpendicularly aligned quartz crystals in two distinct positions: around a coesite inclusion in contact with surrounding pyrope garnet and as a thin rim separating outer garnet rim and second microstructural phase. (2) The following phase represents the second generation of palisade quartz – PQ2. It is distinguished from the PQ1 by the sharp boundary. The quartz is much bigger (0.2-1.5 mm) and dominated by the sub-grain rotation (SGR) and grain boundary migration (GBM) recrystallization mechanism in contrast to the first generation. It is important to note that the presence of a multitude of microstructures is a highly uncommon occurrence, with the final structure and just remnants of previous ones being the most frequently preserved. (3) The final microstructure, MQ, comprises completely recrystallised matrix quartz. It forms a polygonal texture, with sharp grain boundaries and uniform grain size (0.1-0.5 mm). MQ typically shows GBM and SGR. The CL images of different quartz microstructures are homogenous. On the other hand, CL is an easy and straightforward method for identifying or verifying the presence of coesite. Coesite is brighter and distinguishable from surrounding minerals, including quartz. The preliminary results using SAM show different acoustic impedance for various microstructures. This part is still under the calibration stage and requires more data.

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Tectono-stratigraphic evolution of the complex Meliatic mélange based on Th-U-Pb dating of unique euhedral monazites in radiolarian-bearing deposits (Internal Western Carpathians)

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Mélanges offer crucial insights into the subduction-accretion processes and are critical for understanding the tectonic evolution of mountain belts, the dynamics and the geological history of convergent margins. These formations are characterised by a heterogeneous composition, comprising blocks of oceanic crust, sediments, and mantle materials, embedded within a sheared, fine-grained matrix. As a significant component of the geological structure between the Central and Internal Western Carpathians, the Meliata Superunit is a remaining fragment of the Meliata Ocean that witnessed its closure. Its composition is defined by three distinct tectonic subunits: (1) the blueschist-facies Bôrka Nappe in the lowermost position; (2) the low-grade Jurassic sedimentary complex with olistostromes that constitute the Meliata Unit s.s. and (3) an ophiolite bearing polygenous mélange that includes blocks of both unmetamorphosed (upper plate) and high-pressure metamorphosed rocks (lower plate). The present study is focused on the origin and processes associated with the Meliata Superunit, with a particular emphasis on the examination of the fine-grained marine sediments that form the matrix of the polygenous mélange. Findings from two localities indicate that from the metamorphic point of view, the matrix of the polygenous mélange can be differentiated into two groups similar in lithology, but differing in metamorphic overprint. The first group is constituted by unmetamorphosed or low-grade shales that contain Upper Jurassic radiolarians. The second group is composed of phyllites, which exhibit a mineral assemblage that is characteristic of lower to medium-grade metamorphism. Nevertheless, a common indicator of both groups is the presence of distinctive euhedral monazites, whose dating suggests the Late Jurassic – Early Cretaceous age with peak at 150 Ma. The examination of marine sediments indicates that the sedimentation occurred during the Late Jurassic. They were probably partially involved in the metamorphic process during the subduction phase. Subsequently, the exhumation and formation of an accretionary wedge resulted in their integration with unmetamorphosed deposits during the Early Cretaceous period. This integration led to the reworking of the deposits into mélange accompanied by the incorporation of blocks of older rock of variable lithology and metamorphic overprint.

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Biodissolution of sulfides deciphered from experimental incubations and surface analysis by X-ray near edge absorption structure

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Sulfides are common components in metallurgical slags. Even if the volumetric proportion of sulfides in slags can vary within certain limits, these phases are main hosts of metallic elements. Deciphering the progress of sulfides dissolution under abiotic and biotic conditions is crucial for predicting environmental risk associated with slag disposal on the one hand and for estimating the resource potential on the other. Experimental insight into biodissolution of sulfides (chalcopyrite, pyrite, sphalerite and galena) was undertaken implementing long-term solids incubation under abiotic and biotic conditions. For the biotic experiments different microbial strains namely *Pseudomonas fluorescens* and *Acidithiobacillus thiooxidans* were selected to differentiate the complexation and acidification dissolution mechanisms respectively. Experiments involving *A. thiooxidans* also compared the effect of sulfur supplementation to the conditions with no sulfur added. Element leaching rates were tracked over a period of one year with consecutive sampling intervals. Solid alteration was deciphered via Synchrotron based X-ray near edge absorption structure taking into consideration intermediate periods of alterations.

Results demonstrated that sulfides dissolution pattern is specific to individual minerals and depends on microbial strain acting in the experimental system. Overall, *A. thiooxidans* bacteria influenced elements leaching to a higher extent than *P. fluorescens* did. Comparison of *A. thiooxidans* incubations with sulfur supplementation and with no sulfur added showed that external source of sulfur is favorable for bacterial activity on one hand, however, causes passivating effect to solid on the other. It proved that in the field weathering bacteria can acquire sulfur from sulfides resulting in enhanced leaching of metallic elements. This finding also has important implications for development of bioengineered reactors where sulfur addition is a crucial parameter determining process efficiency. Impact of *P. fluorescens* was the most notable for sphalerite mainly because of the most severe siderophore excretion. Insight into surface alteration proved dissolution to occur and the trend was in accordance with element leaching pattern. Short-term dissolution did not result in formation of secondary phases, whereas the features of sulfides resulting from long-term experiments were much more variable.

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The occurrence and origin of dedolomites in cave system from Central Slovenia – microtextural, mineralogical, and geochemical constraints

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Dedolomitization refers to the epigenetic replacement of dolomite by calcite via the influx of low-temperature waters with a high Ca to Mg ratio and/or meteoric affinity. This process has been recognised in Triassic dolostones from Mravljetovo Brezno v Gošarjevih rupah cave (Central Slovenia). Herein, nearly-stoichiometric dolomite ($[Ca_{1.04}Mg_{0.96}][CO_3]_2$) was partially replaced by almost pure calcite ($[Ca_{0.97}Mg_{0.03}]CO_3$) in possible mixing (i.e. schizohaline) environment (Folk & Siedlecka, 1974), during an early-digenetic stage. Later on, dedolomite was eroded (karstified) by meteoric waters, followed by the introduction of reddish to yellowish internal cave sediments. The latter are not only rich in detrital material involving quartz, zircon, apatite, rutile, limestone clasts, and clay minerals, but also contain in-situ precipitated calcite with a peculiar elongated morphology that could be favoured by the presence of organic material within invading fluids (cf. Meldrum & Hyde, 2001). Meanwhile, the dissolution (erosion) of calcite (dedolomite) and preservation of host dolomite has enhanced the formation of boxwork fabrics, though some of the newly-formed pores were occluded by later blocky calcite. As a result, a so-called floating microtexture (i.e. partially calcitized dolomite crystals enclosed by later blocky calcite) has been developed. PAAS-normalized REE patterns for dedolomites are marked by seawater-like signatures typical of oxidizing formation conditions. Meanwhile, the transition from dolomite to dedolomite was followed by the increase of REEs and Ca, followed by the decrease of Mg and Sr. The formation of reddish to yellowish internal sediments, in turn, resulted in the flattening of REE patterns due to the input of clastic material, though the original seawater-like signature was still partially preserved.

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Evolution of lithospheric mantle of the Hessian Depression (Germany)

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Abundant Cenozoic basaltic eruptions occur in the Hessian Depression (Germany), which constitutes the northern continuation of the Upper Rhine Graben. Based on the study of 15 ultramafic xenoliths from the Stöpfling quarry (Puziewicz et al., submitted) we show that combined detailed mineral-chemical and microfabric studies enable to recognize the record of polyphase tectono-metasomatic evolution of lithospheric mantle.

The studied xenolith suite comprises spinel-facies harzburgites, clinopyroxene-poor lherzolites and clinopyroxene-rich lherzolites. Olivine contains 90.1 – 91.5% forsterite. Orthopyroxene and clinopyroxene have highly variable REE, all enriched in LREE relative to MREE/HREE. Spinel Cr# varies from 0.17 to 0.46. The $^{87}Sr/^{86}Sr$ ratios measured *in situ* in clinopyroxene vary from 0.703969 (±37 1σ) to 0.708615 (±149 1σ). The peridotites typically have well defined olivine-orthopyroxene crystal-preferred orientation, whereas clinopyroxene is oriented independently, reflecting its secondary addition to an originally refractory harzburgite protolith. The latter is preserved in two harzburgites with highly depleted compositions, affected only by carbonatitic metasomatism. Other harzburgites and clinopyroxene-poor lherzolites were metasomatized by carbonated silicate or alkaline silicate melts. The clinopyroxene-rich lherzolites preserved relics of MORB-like refertilization, overprinted by alkaline metasomatism analogous to that affecting the rest of the rocks. The two-pyroxene equilibration temperatures (940-1050ºC) suggest that Stöpfling xenoliths sample a rather narrow ~8 km depth interval of the mantle lithosphere.

The Stöpfling mantle profile probably records a two-stage tectono-metasomatic evolution, comprising (1) lithosphere exhumation and melting during flattening of the Variscan orogen root witnessed by symplectites after garnet, and (2) further local lithosphere thinning during Alpine rifting, accompanied by multiple local chromatographic-style metasomatic episodes that culminated in volcanism as well as xenolith entrainment and transport to the surface.

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New Insights into the Thermodynamics of Apatite Supergroup

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Apatite is one of the most numerous mineral groups encompassing a selection of inorganic compounds with a common structural arrangement and symmetry. Their broad chemical composition and wide-ranging formation conditions make them the most common accessory minerals in all types of rocks and the most useful supergroup of minerals in industry (Hughes & Rakovan, 2015). The apatite supergroup is expanding with new members every year. However, the thermodynamic properties of most apatites are still drastically unexplored due to the complexity of their structure and specific chemical composition (including the presence of halides) which makes experimental determination of thermodynamic state functions (TSFs) very difficult.

In order to fill gaps in thermodynamic databases, various methods of estimating TSFs have been developed for decades (Jain et al., 2013). This study proposes a new method for predicting TSFs for apatite based on splitting the supergroup into subgroups (Puzio & Manecki, 2022). For this purpose, we collected literature experimental data on TSF and molar volume (V_m) for phosphates, arsenates and vanadates, and their synthetic analogs belonging to the apatite supergroup containing Ca, Sr, Ba, Pb, and Cd in the cationic Me^{2+} position and F, OH, Cl, Br and I in the halide X position. The apatite supergroup was shown to divide into distinct subgroups (populations) consisting of $Me_{10}(AO_4)_6X_2$ with the same Me^{2+} cations and tetrahedral AO_4^{3-} anions, but with different anions in the X position. Very good linear correlations between TSF, V_m and various physicochemical parameters allowed predicting new TSF values for apatite and similar synthetic materials.

The simultaneous application of the updated TSF database made it possible for the first time to see trends in variability and specific thermodynamic relationships within and between different apatite subgroups. The results of this work open up many new avenues and will enable the exploration of syntheses of new apatite materials that meet the current challenges of civilization, e.g. in the field of green technology.

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Biogeochemical effects on the origin and variability of authigenic minerals in anoxic Baltic Sea sediments

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The Baltic Sea is a shelf sea characterized by relatively shallow depth and high nutrient and organic matter input resulting in increased productivity compared to the open ocean. Biogeochemical processes acting here have a significant impact on the entire environment and play a key role in cycling of major and trace elements. In order to assess the influence of these processes on mineral composition of sediments, sediment samples with porewater were collected from three sites that differ in local biogeochemical environment: (i) an active pockmark with methane seepage and infiltration of freshwater (MET1-MP), located in the Gulf of Gdańsk, (ii) a shallow-water site with a large regular accumulation of methane (MET2), located in the Puck Bay, and (iii) a reference deep-water site with no methane nor freshwater in the sediments (ZGG), located within the Gdańsk Deep. A comprehensive description of biogeochemical systems in upper 100 cm of the sediments was achieved by combining sediment mineralogy, pore water chemistry, thermodynamic modeling of mineral-solution equilibria, and microbial community analysis (16S rDNA metabarcoding). The sediments were characterized using X-ray diffractometry (PXRD), light and electron microscopy (SEM-EDS), simultaneous thermal analysis (STA), Mössbauer spectroscopy, and sequential chemical extractions.

All the sediments are fine-grained and rich in organic matter. The mineral skeleton is similar and includes sheet (alumino)silicates (micas, illite, chlorite, kaolinite and mixed-layer clay minerals), alkali feldspars and quartz, accompanied by accessory minerals (titanium oxides, zircon, apatite, barite etc.). Authigenic minerals occur in small amounts and include amorphous silica, carbonates (calcite, Mg-calcite, dolomite and siderite) and iron sulphides (chiefly framboidal pyrite). Preliminary results indicate that differences in the proportions of authigenic minerals observed between the sites can be explained by differences in local biogeochemical conditions and the processes that shape them.

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Constraints on Gondwana passive margin paleogeography from metavolcanic-sedimentary basement of the Western Carpathians

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Understanding the European geological history requires reconstruction of the original positions and subsequent evolution of the Gondwana-derived crustal segments that are now included in the Variscan and Alpine orogenic belts. The Western Carpathians, a component of the Alpine–Carpathian belt, is one such important crustal block. The early paleogeography and tectonic evolution of the Western Carpathian pre-Variscan basement remain uncertain, due to the lack of geochronological data and intense Variscan and Alpine overprints. The metavolcanic-sedimentary basement units of the Western Carpathians (Tatric, Veporic and Gemeric units) were investigated using U–Pb dating and Hf isotopic analysis of detrital zircons as well as whole-rock geochemical data.

The detrital zircon age populations show that the early Cambrian–Middle Ordovician sequences were supplied predominantly by Ediacaran (ca. 600 Ma) zircons. Contributions from older, Stenian–Tonian (ca. 1.2–0.9 Ga) and Paleoproterozoic cratonic (ca. 2.2–1.8 Ga) sources were comparatively minor. The Hf isotopic patterns (εHf(t) values ranging from –20 to +12) of the Ediacaran zircons indicate significant interplay between mantle-derived magmatic sources and mature crustal material, typical of continental magmatic arcs. In contrast, the generally negative εHf(t) values (–15 to +4) of the cratonic zircons document recycling of pre-existing crust. The youngest stratigraphic member of the sequence also contains large amount of early Paleozoic zircons with mostly negative εHf(t) values (–10 to –2). The detrital zircon age spectra, their Hf isotopic composition and whole-rock geochemistry of the studied Western Carpathian sequences are interpreted in terms of deposition on the Cambrian–Silurian passive margin.

These detrital zircon U–Pb age and Hf isotope data from the Western Carpathians have been compared with extensive datasets published from possible source cratons and other Gondwana-derived crustal segments to test their possible primary linkages. The correlations revealed striking similarities in both zircon age distributions and Hf isotopic patterns to other parts of the Ediacaran (Cadomian) continental magmatic-arc. Cratonic detritus is linked to the Saharan or East African parts of northern Gondwana, whereas the early Paleozoic clastic material was derived from local sources. The detrital zircon age and Hf isotopic record of the Western Carpathian basement allows to propose a new paleogeographic reconstruction of the northern African part of the Gondwana passive margin.

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Deep structure of the Western Carpathians in the light of seismological and potential field data

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Although the Carpathians have been the object of research for 150 years and their surface geology is well known, the deep structure remains the subject of various hypotheses. Therefore, only geophysical research can support new geological models in this area. This study aims to explore the existence of a tectonic suture associated with the Pieniny Klippen Belt (PKB) and the potential remnants of the Czorsztyn Ridge using passive seismic methods and potential field data.

A total of 18 seismic stations were deployed, with careful site selection to minimize human-induced noise and ensure reliable data collection. These stations continuously monitor seismic activity, recording data that is stored on SSDs or SD cards and transmitted to an online server. Using the data collected over the past year, Common Conversion Point (CCP) stacks were generated. These stacks offer a detailed picture of the subsurface, highlighting variations in seismic wave velocities that correspond to different geological layers.

Although our results are preliminary and the experiment will continue for another two years, its key findings so far can be summarized as follows:

- The southward Moho step of about 10 km, followed by a gap in the Moho discontinuity between km 100 and 140 of the profile correspond to tectonic suture between the European plate in the north and the ALCAPA microplate in the south. The subducted European plate shows low-angle southward underthrusting beneath ALCAPA.
- The Outer Western Carpathians do not reveal a purely thin-skinned tectonic style as previously believed. There is a deep detachment within the European crust beneath the flysch nappes of the Outer Carpathians.
- The PKB is linked to the basal detachment of the Central Carpathian nappes.
- The ALCAPA middle-lower crust is wedged into the European slab. No remnants of the Czorsztyn Ridge are observed at the contact of the European and ALCAPA plates.

Preliminary assessment of the gravity and magnetic data has shown that the PKB is represented by a deep-seated anomaly and reaches at least 15 km in depth. The qualitative analysis of potential field data reveals the presence of three major elements in the deep basement of the Western Carpathians corresponding to the ALCAPA, European Platform, and a previously unrecognized wedge-shaped block in the east. The PKB follows the boundary between the ALCAPA and the remaining two domains.

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Assessment of the maturity of the Central Carpathian Palaeogene Basin using biomarker and non-biomarker parameters

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This study examines the thermal maturity of sedimentary rocks of the Central Carpathian Paleogene Basin (CCPB) through an integrative approach, employing both biomarker and non-biomarker parameters. Recognizing thermal maturity as a crucial factor in petroleum exploration, the research utilizes a combination of methodologies to achieve a more precise assessment. Key focus areas include particularly aromatic and aliphatic biomarker ratios. Vitrinite reflectance values, calculated using the methylphenanthrene index (MPI1), are found to effectively characterize a broad thermal maturity range across the CCPB. The findings reveal a significant thermal gradient, with the Spiš Basin exhibiting the highest maturity levels. The described increase in palaeotemperatures is documented also in the Mesozoic nappes of the Tatra Mts (Staneczek et al., 2024b). The Orava Basin and Šariš Upland display lower maturity, indicated by the presence of immature organic matter and lower overburden thickness. Yet, Orava Basin seems to be the least mature CCPB area which is additionally supported by the presence of immature organic compounds (Staneczek et al., 2024a). A comparative analysis of illite/smectite-derived paleotemperatures with biomarker methods shows strong agreement in higher maturity zones, although overestimations are noted in less mature areas by the former. This study underscores the limitations of relying on a single maturity indicator and advocates for a comprehensive, multi-parameter approach to reconstruct palaeotemperatures accurately. The results enhance the geological understanding of the CCPB and offer critical insights for a potential hydrocarbon exploration in the region, establishing the CCPB as a model area for evaluating thermal maturity indicators.

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Geochemical anomalies in the soils of the Szczawnica area (Western Carpathians, Poland) – a link to magmatic rocks?

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In the Polish part of the Outer Carpathians, Neogene andesites occur within the Magura Unit and Pieniny Klippen Belt. They crop out as a sequence of intrusive bodies, called the Pieniny Andesite Line (PAL; Birkenmajer, 1987). Due to the small size of the intrusions, the contact zone and hydrothermal alterations around the PAL are poor. The best developed contact zone is around intrusion from the Jarmuta Hill (Małkowski, 1918).

New geochemical surveys indicate that the impact of the intrusions is much more pervasive than those observed in the outcrops of the surrounding rocks. Geochemical data (the total content of selected elements) from the set of one thousand soil samples were collected from the soil B horizon in the northern vicinity of Szczawnica. The 20-square-kilometers area of regularly distributed samples is limited to the west by the Dunajec river and to the east by the Sopotnicki creek, and covers the Szczawnica area of PAL.

The analyses of the spatial distribution and statistical variability of the geochemical data allowed to recognize that the anomalous contents of Cu, K and Sr occur in the western, and southern borders of the study area and well correspond with the intrusion outcrops. Moreover, some anomalies extend beyond the known localities of andesites, suggesting the presence of yet undiscovered magmatic bodies in the subsurface. The Pb content anomalies occur in the area outside the Szczawnica area of PAL, whereas the anomalous contents of As and Zn are evenly scattered over the entire area.

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Sequestration of arsenic from water by the precipitation of mimetite $Pb_5(AsO_4)_3Cl$

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Arsenic contamination in water is a major concern due to geogenic sources or mining, fossil fuel burning, and arsenic-based products. Mining and rock excavation in urban and industrial projects often generates large amounts of rock leachate or waste that can lead to acid mine drainage (AMD), with low pH and high levels of toxic elements like As, Pb, Cd, Cu, Fe, and Zn. Traditional methods for arsenic removal from water often require separate treatment plants. This project aims to test a new, innovative approach using small, mobile treatment facilities. We propose to explore an alternative pathway that has been poorly researched before, and which is quite simple: induced precipitation of As - bearing, insoluble crystalline phase - lead chloride arsenate $Pb_5(AsO_4)_3Cl$ (mimetite). Lead will be sourced from the dissolution of lead carbonate (cerussite). Fundamental studies assessed the feasibility of developing mobile reactors for removing arsenic from water, such as waste rock leachate or AMD.

A series of experiments was conducted to develop specific modules for a reactor designed to treat arsenic-contaminated waters. Initially, As-bearing aqueous solutions were prepared to mimic the composition of natural water samples containing arsenic. During the pretreatment, chloride ions (Cl^-) were introduced, as they are essential for subsequent processes. Solutions were reacted with synthetic lead carbonate (cerussite) powder for periods ranging from 1 to 24 hours. In the following step the excess Pb was removed by introducing a phosphate reagent or synthetic hydroxylapatite ($Ca_5(PO_4)_3OH$) which results in precipitation of pyromorphite ($Pb_5(PO_4)_3Cl$), effectively sequestering lead. Finally, the solutions were treated with conventional liming with calcium carbonate ($CaCO_3$) to raise the pH and lower the concentration of other potential contaminants, ensuring comprehensive purification of the water. Samples of solutions were collected before and after each of the steps and analyzed using ICP-MS, AAS, and UV-Vis spectrophotometry. Solid state was studied by XRPD and SEM-EDS. The results indicate that the process is efficient lowering As concentration from 5 mg/L to the levels below 0.01 mg/L regardless the presence of other cations or anions in the solution.

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Raman Spectroscopy of CO_2 inclusions in olivines and pyroxenes as a tool for studying magmatic evolution – preliminary data from Strzelin Volcanic Field nephelinites

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Magmatic minerals often contain fluid inclusions, with CO_2 as one of the most common components. Studying the density of these inclusions is key for calculating the pressure conditions during their formation, which allows for the reconstruction of the crystallization depth and magmatic ascent history. This research uses Raman spectroscopy to analyze CO_2 inclusions in olivines and pyroxenes from Cenozoic nephelinites in the Strzelin Volcanic Field, near the northeastern edge of the Bohemian Massif (Awdankiewicz et al., 2016).

The Raman spectrum of CO_2 is characterized by two primary bands at 1285 and 1388 cm^{-1}. The distance between the bands, known as the Fermi diad, is directly proportional to the density of the fluid inclusion. Through precise mathematical calculations, the pressure within these inclusions can be determined. When combined with the formation temperature, this approach provides a robust geothermobarometer, offering insights into the magmatic processes (Yamamoto & Kagi, 2006).

Two studied nephelinite samples from vicinity of Kowalskie village contain 5-10% olivine and pyroxene phenocrysts by volume. The obtained Raman spectra indicate CO_2 inclusion densities in the range 0.19 – 0.89 g/cm^3. Assuming formation temperatures of ca. 1100-1200°C of the nephelinite magma from which the olivines crystallized (cf. Winter, 2010) the pressures and corresponding depths are, respectively, 6-6.5 kbar and 21-23 km. These values can be interpreted as crystallization depths of the studied minerals from the nephelinite magma in relatively deep parts of the magmatic system of the Strzelin area Cenozoic volcanoes, at the lower to middle crustal levels. Further work on the nephelinites and other associated volcanic rocks (basalts, trachybasalts) should reveal more details on the magmatic processes that influenced formation and differentiation of magma in this area.

It is believed that Raman spectroscopy can be an efficient, non-invasive method for rapidly, near real-time assessing the depth of magma formation with minimal sample preparation. This technique holds great potential for advancing our understanding of magmatic evolution and the conditions under which these inclusions were formed.

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Metamorphic history of the Orlica-Śnieżnik dome (Sudetes, Bohemian Massif): Insights from phase diagram modeling and quartz-in-garnet barometry

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We studied metapelites and metapsammites of the volcano-sedimentary successions exposed in the Orlica Śnieżnik Dome (OSD), the Central Sudetes, using quartz-in-garnet elastic barometry coupled with conventional geothermobarometry and phase equilibria modelling. This allows us to compare the metamorphic history of the western and eastern parts of the OSD using the same methods.

Our new data demonstrates similarities and some differences in the metamorphic records preserved in the inspected rocks exposed in both parts of the OSD. The investigated rock successions have undergone three metamorphic events M1 to M3. The records of the suspected M1 event are poorly preserved in the selected samples and comprises rutile grains and phengitic white mica with high-Si content. Based on conventional geothermobarometry the, M1 event may have occurred at P-T conditions of ca. 15 to 17 kbar and 460 to 590º C. The well preserved metamorphic events M2 and M3 were reconstructed using the semi-automated routine of Moynihan and Pattison (2013) based on garnet zoning and utilising quartz-in-garnet elastic barometry. The M2 event shows prograde characteristics, although the P-T conditions of metamorphism vary depending on the tectonic domain. In general, metapsammites from the Młynowiec Domain (eastern part of the OSD) and its equivalent, the Wyszki Unit (western part of the OSD), show P-T paths characterised by an increase in P and T from ca. 7 kbar to ca. 10.5 kbar in the temperature range of ca. 530 to 580ºC. On the other hand, the metapelites exposed in both parts of the OSD bear a record of the M2 event, which is characterised by an increase in P to maximum values of ca. 6.5 kbar. The last M3 event shows a decrease in P to minimum of ca. 3.5 kbar. The described metamorphic episodes M2 and M3 underwent at temperature of ca. 500 to 570ºC. The obtained results may indicate that rock successions exposed in the OSD showing different metamorphic history may represent fragments of different tectonic units.

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Preliminary studies of detrital zircons from Istebna Formation (Jasnnowice, Olecka stream, Western Outer Carpathians, Poland)

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Detrital zircons from the sandstones of the Upper Istebna Beds (Upper Istebna Sandstone - Paleocene) were analyzed to obtain new information and supplement the existing data on the provenance and history of the Silesian Ridge. Twelve sandstone samples were collected from an outcrop in the Olecka stream on the border of Poland and the Czech Republic (Western Outer Carpathians). The research material was analyzed using optical microscopy, heavy mineral separation, cathodoluminescence (CL) of zircon crystals mounted in epoxy, and LA-ICP-MS U-Pb dating of zircon crystals.

Approximately 1200 zircon crystals were separated, and 850 were selected for subsequent analyses. The morphology of zircons indicates that the grains have proportions from 1:1 to 1:4. Most zircon crystals show oscillatory zoning, typical for igneous crystallization, and variable intensity of cathodoluminescence.

Based on the selected spots, the U-Pb zircon age analyses were performed. Two dominant zircon populations were observed – Variscan (all samples, 310–380 Ma) and Cadomian (11 samples, 531–636 Ma), as well as a much smaller Caledonian (7 samples, 460–486 Ma).

Analysis of the obtained data shows that the samples indicate a similar age to previously analyzed crystalline samples (granitoids, gneisses and granulite) from Kamesznica and Targoszówka (Szczuka et al., 2022), as well as to the results of the conglomerate matrix and sandstone from Kamesznica (Szczuka et al., 2022).

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“Metal leakage from orthodontic appliances chemically alters enamel surface during experimental in vitro simulated treatment”, i.e. why *bio* approach is not enough

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Orthodontics is a rapidly developing area within the field of dentistry and business. Clinical studies predominate in the literature, although laboratory approaches are also conducted with varying degrees of community approval. The dental market and scientific discourse do not typically incorporate the results of basic mineralogical research, despite the fact that the subject of research is, in essence, minerals. A critical oversight in the discussions is the neglect of mineralogical studies, which suggest that the assimilation of various metals (e.g., those of orthodontic appliances) apatites may influence its stability and lead to decalcification, the initial stage of caries.

This work demonstrates how a well-designed mineralogical experiment can support research on the biomineralization of human tissues in ways that clinical studies cannot. As our article points out (Topolska et al., 2024): *“A total of 107 human enamel samples were subjected to simulation involving metal appliances and cyclic pH fluctuations over a period of 12 months in four complementary experiments. The average concentrations and distribution of Fe, Cr, Ni, Ti, and Cu within the enamel before and after the experiments were examined using ICP-MS and LA-ICP-MS techniques. The samples exposed to the interaction with metal appliances exhibited a significant increase in average Fe, Cr, and Ni (Kruskal-Wallis, $p < 0.002$) content in comparison to the control group. The outer layer, narrow fissures, and points of contact with the metal components showed increased concentrations of Fe, Ti, Ni, and Cr after simulated treatment, in contrast to the enamel sealed with an adhesive system.”* The study has proven for the first time that the presence of metal materials in the oral cavity during treatment affects the chemical composition of enamel. The results and methodology can be employed to improve both orthodontic techniques and materials and to develop caries prevention methods based on metal systems with aseptic properties.

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Reevaluation of P-T conditions of eclogite facies metamorphism in the Western Gneiss Region, Norwegian Caledonides

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Eclogites in the Western Gneiss Region (WGR) experienced (ultra-)high pressure (UHP) metamorphic conditions during Caledonian orogeny. Their composition and pressure-temperature (P-T) conditions vary along the WGR, with the peak metamorphic conditions increasing from the south to the north (Krogh, 1977). For this study, we selected eclogites from nine localities (Drøsdal, Vårdalsneset, Verpeneset, Halnes, Saltaneset, Grytting, Ulsteinvik, Korveneset and Solholmen) along the western margin of WGR. The main focus is to evaluate selected methods, improve the prograde to peak estimate of the single localities and provide a peak P-T gradient for the whole WGR. The mineral assemblage differs in eclogites from the southern localities (garnet, clinopyroxene, phengite, quartz, amphibole, kyanite, zoisite, rutile, zircon) and northern localities (garnet, clinopyroxene, orthopyroxene, amphibole, rutile, zircon) as well as the mineral chemistry of the main phases. The composition of garnet changes from $Alm_{0.41–0.57}Grs_{0.15–0.31}Prp_{0.10–0.37}Sps_{0.01–0.07}$ in the south to $Alm_{0.33–0.46}Grs_{0.09–0.13}Prp_{0.41–0.56}Sps_{0.01–0.04}$ in the north. Clinopyroxene is characterized by X_{Na}=0.40-0.52 and X_{Fe}=0.12-0.19 in the south and X_{Na}=0.20-0.29, X_{Fe}=0.12-0.17 in the north. The occurrence of coesite and polycrystalline quartz in Saltaneset (found during this study), Verpeneset and Ulsteinvik localities is evidence of UHP conditions. We estimated the P-T conditions of the eclogites utilizing a combination of Grt-Cpx-Phe, Zr-in-rutile, Ti-in-quartz and quartz-in-garnet geothermobarometry. The observed mineral assemblage allows for the reconstruction of the prograde history only for the southern eclogites. The latter display a prograde path from amphibolite facies of ca. 1.08 ±0.16 GPa and 627 ±31°C up to eclogite facies conditions. The peak P-T conditions vary from 2.74 ±0.32 GPa at 704 ± 65°C in the south to about 5.40 GPa at 840 ±30°C in the north. Considering most of the studied localities, the calculated metamorphic field gradient in WGR is approx. 5ºC/km. This study supplements the knowledge of WGR providing prograde P-T paths and confirming previous estimates of the field gradient.

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Experimentally induced hydrothermal transformation of chevkinite-(Ce): results and conclusions for subsequent experiments

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Chevkinite group minerals (CGM) are titanium-rare earth element (Ti-REE) silicates that occur in a variety of geological environments. Recent studies have emphasized the importance of understanding REE behavior during the hydrothermal alteration of alkaline rocks, which plays a significant role in rock formation and the genesis of REE ore deposits. To investigate this, experiments were carried out on chevkinite-(Ce) using a cold-sealed autoclave in a high-pressure hydrothermal setup, designed to replicate the mineral assemblages and hydrothermal fluids associated with alkaline rocks. The experiments were conducted at temperatures ranging from 500 to 600°C and pressures of 200 to 400 MPa, with durations varying between 21 and 63 days. These experiments produced various REE-bearing mineral phases, including britholite-(Ce), fluorbritholite-(Ce), monazite-(Ce), and minerals of the epidote supergroup. Other LREE-rich phases such as gagarinite-(Ce) and titanite were also synthesized. These findings shed light on mineral transformations and REE mobilization during hydrothermal processes in alkaline rocks. The least expected product of these transformations is monazite-(Ce). Additionally, there was a surprisingly small amount of minerals from the allanite group among the products. The appearance of monazite is most likely due to phosphorus-rich substrates added to the system, while the absence of allanite-(Ce) may be due to insufficient Ca in the system. The biggest problem that emerged during the study was the imbalance of cations in the structure of the various products, which may indicate that the system is out of equilibrium. This situation, which is very rare in nature, is due to the closed nature of the experimental environment. As a conclusion, in addition to the processes already described (Macdonald & Bagiński, 2022) it is important to highlight the advantages and disadvantages of the experiments used. The interpretation of results is complicated by the overly complex nature of the substrates in question. Furthermore, the inherent complexity of hydrothermal transformations cannot be reduced to simple chemical equations. As a result, the replication of natural conditions in a laboratory setting is impractical, representing a significant challenge for future research.

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New insights into the age and genesis of magmatic intrusions in Krutfjellet Nappe, Upper Allochthon, Scandinavian Caledonides

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In the central Scandinavian Caledonides, the Upper Köli Nappes Complex of the Upper Allochthon forms discontinuous tectonic lenses; the Norra Storfjället, Södra Storfjället and Krutfjellet lenses. In the Norra Storfjallet lens, the Krutfjellet Nappe comprises amphibolite facies schists and several igneous intrusions, notably the Artfjället gabbro (434 ±5 Ma; Senior & Andreiessen 1990), which cuts through older volcano-sedimentary sequence and the Vilasund granite (445 +24/-6 Ma; Stephens et al., 1993). In the Krutfjellet lens, the Krutfjellet Gabbro dates to ca. 445 Ma (Saalmann et al., 2021). These ages align with contact metamorphism at ca. 437 Ma; (Mørk et al., 1997). The age of the lower volcanic unit has not yet been established.

Our new geochemical study confirmed the presence of two suits of igneous rocks in the studied Norra Storfjället lens of Krutfjellet Nappe, while the U-Pb isotopic studies of zircon provided new ages to help understand relations between rocks of both volcanic units. The lower volcanic unit contains rocks of island arc affinities. U-Pb zircon ages obtained for three samples of metamafic rocks imply their protolith formation at ca. 466 Ma. The upper volcanic unit, comprising Artfjället gabbro, has a within-plate affinity. We have redefined the age of Villasund granite to 467 Ma, suggesting the granite had been intruded far before Artfjället gabbro and belongs to the lower volcanic unit. However, contact metamorphism during the gabbro emplacement has affected the granite and resulted in the growth of hydrothermally induced, high-U zircon rims, which may have influenced previous whole-grain zircon dating.

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Does iron speciation correlate with the reservoir properties of rocks? ^{57}Fe Mössbauer study of Miocene sediments, Carpathian Foredeep

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^{57}Fe Mössbauer spectroscopy was used to identify iron species in Miocene sedimentary rocks of the claystones-mudstones-sandstones type. The samples come from the Carpathian Foredeep from a location near Przemyśl area and were obtained from drill cores probed below 3000 m depth. It was found that iron atoms occur as divalent ions in silicates Fe^{2+}(Si), carbonates Fe^{2+}(C) and sulfides Fe^{2+}(S). The area of Mössbauer sub-spectra made it possible to determine the relative distribution of iron between the above groups of minerals. The obtained results (Fig. 1) were normalized taking into account the mineral composition identified by X-ray diffraction (XRD) and were correlated with the reservoir properties of the studied rocks. The normalized ratio of iron in carbonates to silicates [Fe^{2+}(C) / Fe^{2+}(Si)] and the irreducible water saturation in the effective porosity obtained from nuclear magnetic resonance (NMR) were used as correlation parameters.

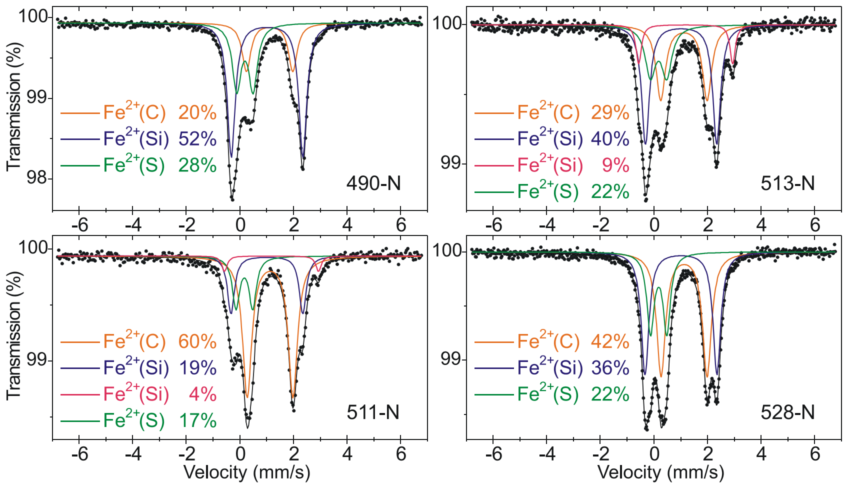

Figure 1. ^{57}Fe Mössbauer spectra of Miocene reservoir rocks. The relative areas of the sub-spectra corresponding to the distribution of iron atoms into carbonates Fe^{2+}(C), silicates Fe^{2+}(Si) and sulfides Fe^{2+}(S) are shown.

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Compositional zoning in spessartine from pegmatite from the Wiry mine in the Gogołów-Jordanów serpentinite massif (Sudety Mts, SW Poland)

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Granitic and hybrid pegmatites occurring within the serpentinite massifs of the The Central-Sudetic ophiolite are extremely rare and so far their occurrences have been confirmed in three locations: Mt. Szklana Mine (Szklary) in the Szklary serpentinite massif, the Wiry and the Jordanów Śląski mines in the Gogołów-Jordanów serpentinite massif. Pegmatites from these locations are interesting in terms of the mineralogical composition and petrology of pegmatites mainly due to complex petrogenesis, including the (1) generation of pegmatitic magma, (2) migration of pegmatitic magma into the basic or the ultrabasic rocks and (3) contamination of granitic magma by the components from the surrounding rocks. In the Wiry mine, pegmatite veins about 30-60 cm thick were emplaced discordantly cutting serpentinites and accompanying magnesites. The mineral composition of the studied pegmatite includes garnet (Fe-rich spessartine), phlogopite, muscovite, greenish beryl, fluorapatite, cassiterite, the columbite-group minerals and silicate glass with composition close to the Mg-rich chlorite. Fe-rich spessartine is the most interesting mineral in terms of petrogenesis, as it is characterized by the presence of a compositional zoning, not usually found in garnet crystals in pegmatites. In the studied garnet, four zones characterized by different chemical composition can be distinguished: (1) core-zone $Mn_{2.12}Fe^{2+}_{0.82}Mg_{0.04}Ca_{0.01}(Al_{1.94}Fe^{3+}_{0.06})(Si_{2.95}P_{0.02}Al_{0.03})O_{12}$; (2) a mantle-zone $Mn_{2.16}Fe^{2+}_{0.78}Mg_{0.04}Ca_{0.02}(Al_{1.91}Fe^{3+}_{0.09})(Si_{2.93}P_{0.03}Al_{0.04})O_{12}$; (3) an inner rim-zone $Mn_{1.90}Fe^{2+}_{0.98}Fe^{3+}_{0.07}Mg_{0.05}Ca_{0.01}(Al_{1.97}Fe^{3+}_{0.03})(Si_{2.95}P_{0.02}Al_{0.02})O_{12}$; and (4) an outer rim-zone of $Mn_{1.46}Fe^{2+}_{1.42}Mg_{0.07}Fe^{3+}_{0.04}Ca_{0.01}(Al_{1.97}Fe^{3+}_{0.03})(Si_{2.96}P_{0.01}Al_{0.03})O_{12}$. In terms of trace element content, the most interesting zone is the mantle-zone, where the highest SnO_2 contents were recorded (up to 0.21 wt.%, up to 0.01 Sn atom per formula unit). Fluorapatite, Mn-Fe±Ca±Mg±Na phosphates (mainly triploidite, minerals of the graftonite group and minerals of the alluaudite group), cassiterite and the columbite group-minerals were recognized as tiny inclusions within the different garnet crystals. The chemical composition of all of the above minerals, together with the chemical composition of the host garnet, are useful in the context of determining the geochemical maturity of the pegmatite melt, which is crucial in the context of the petrogenesis of a pegmatite.

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Redistribution of lead in heated zircons from rock samples differing with ages

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Zircon ($ZrSiO_4$) is important geochronometer, as it incorporates U, Th and excludes Pb during crystallization, hence the assumption that it accumulates only radiogenic Pb. Zircon is chemically and physically robust and resistant to diffusion of Pb at temperatures below 900ºC, all these features allow for deciphering history of Earth crust. Since zircon is the most significant for U-Pb isotopic dating, Pb mobilisation, including study of its diffusion, is important for understanding changes of chemical composition of zircon and meaning of received data. Studying diffusion in zircon allows to understand thermal histories of rocks and interpreting Pb isotopic signatures. There were many experiments involving zircon heating, during which Pb migration and loss were documented (experiments of Shestakov and Magomedov). Presence of features such as cracks, dislocations and cleavage surfaces, which are the paths of lead mobilisation and its transport in grains, have influence on U-Pb systems. Forming Pb lead nanospheres is the another important factor that influences dating.

For heating experiments two samples were selected, one of them Variscan tonalite with uniform age and domains and different U content and the second sample of Cambro-Ordovician gneiss with rims and inherited cores, with different age an non-uniform U distribution. Zircon grains from both samples were heated for 1, 3 and 6 months at temperature 1400ºC. After heating cathodoluminescence images of grain were performed and content of U, Th and Pb was measured. Sixteen zircon foils were analysed on transmission electron microscope and lead nanospheres were observed in 4 specimens. The occurrence of the Pb spheres was observed only in samples with ages exceeding 2 Ga, with different concentration of U and time of heating. Due to low diffusion rate of Pb in zircon the age of grain, hence time is the main factor which plays important role in lead nanospheres formation.

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Santacrucian not Timanian? Sources of detritus in the Paleozoic succession of COSC-2 borehole

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The COSC-2 deep continental drilling project yielded more than 2 km of continuous core through the thin-skinned thrust system of the Caledonian orogen in Sweden. Here we present a detrital zircon geochronological study of the rocks recovered from the Palaeozoic section of the borehole. The studied section comprises a continuous Lower Cambrian (?) to Lower Ordovician (?) parautochtonous to autochtonous succession and is characterized by changing detritus sources along the profile. The Lower Cambrian (?) part of the succession exceeds 350 m thickness and is locally sourced from the Transcandinavian Igneous Belt with progressive change towards a Sveconorwegian provenance. The upper part of the autochthonous succession a few meters below the Alum Shale Formation is characterised by an input of late Neoproterozoic-Cambrian grains with several other exotic populations. The maximum depositional age is estimated to be 530.5 ±4 Ma for the upper part of the Lower Cambrian succession using the maximum likelihood age algorithm. The Alum Shale Formation, although tectonised in its shaly middle part, is continuous, suggesting a complete Middle Cambrian to Lower Ordovician section. Above the Alum Shale Formation, in the parautochtonous part of the drilled section, the detritus provenance reverts to Sveconorwegian source areas typical for Ordovician greywackes of the Lower Allochthon. Comparison of the detrital zircon geochronological data from Lower-Middle Cambrian of Baltica suggests that in this interval, almost all of the studied successions show a flux of late Neoproterozoic-Cambrian detritus. Potential sources of this flux might be either related to the uplift of the Timanides in the north or the Scythides/Santacrucides in the south. Statistical analysis shows that in Central Scandinavia the southerly source is more likely, although the flux time interval was much shorter than in southern Scandinavia, where the young detritus extends into the Lower Ordovician interval. This change of the detrital sources is most likely related to the interaction between Baltica and Avalonian terranes. The Palaeozoic succession of the COSC-2 borehole is therefore a unique opportunity to study a continuous section influenced by long distance tectonic processes.

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XXIXth Meeting of the Petrology Group of the Mineralogical Society of Poland

"Orogenic processes in the Western Carpathians and related mountain belts"

Field trip guide

A panoramic SE-NW view of Baranec and the Roháče ridge as seen from Kończysty Wierch (photo: M. Bukała)

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Pre-conference field trip: *a transect through crystalline basement of the Western Tatra Mountains*

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Introduction

The Tatra Mountains form the highest mountain range in the Carpathians and are located along the Polish-Slovak border. The highest sharp Alpine peaks, exceeding 2500 masl, occur in the High Tatra Mts., while the Western Tatra Mts. do not exceed 2300 masl and reveal a more gentle landscape. The Tatra Mts. represent the northernmost expression of the pre-Mesozoic basement in the entire Alpine belt in Europe. This basement, the Tatric Superunit (Fig. 1), is dominated by granitoids and metamorphic rocks of various grade, mostly consolidated during the Variscan Orogeny. The Alpine orogenic activity shaped the current tectonic architecture of the Tatra Mts. with a crystalline basement in a (par)autochthonous position, tectonically overlain by the so-called cover nappes composed of Mesozoic sedimentary units. The final uplift of the Tatra Mts. took place in the Neogene, during the terminal stage of the Alpine Orogeny in the Western Carpathians.

Crystalline basement of the Western Tatra Mountains

The crystalline basement of the Western Tatra Mountains belongs to the Tatric Superunit of the Western Carpathians, a top-to-N Alpine allochthon formed during the closure of the Alpine Tethys Ocean. It is divisible into the top-to-S Variscan Lower and Upper tectonic units that differ in metamorphic grade and age (Janák, 1994). The Lower Unit, composed mostly of mica schists (Fig. 2), underwent amphibolite facies metamorphism at ca. 330-320 Ma (e.g., de Doliwa Zieliński et al,. this issue). In contrast, the Upper Unit is composed of orthogneisses, paragneisses, calc-silicate rocks and amphibolites. Rare eclogites document high-pressure metamorphism (Janák et al., 1996) dated to ca. 367 (Burda et al., 2021) or 354 Ma, (Kohút et al., 2023). This event was followed by decompression to granulite facies conditions accompanied by partial melting (Janák et al., 1999) and emplacement of a syn-orogenic granitic sheet at ca. 352-345 Ma (see below). The architecture of this Variscan inverted metamorphic sequence, i.e. high-grade rocks in the hanging wall and lower-grade ones in the footwall, is interpreted to be an effect of crustal thickening and mid-crustal thrusting resulting in the steep P-T-t gradient structurally upward, which resembles a tectonometamorphic inversion known from the Himalaya-Tibet Orogen (e.g., Janák et al., 1999; de Doliwa Zieliński et al., this issue).

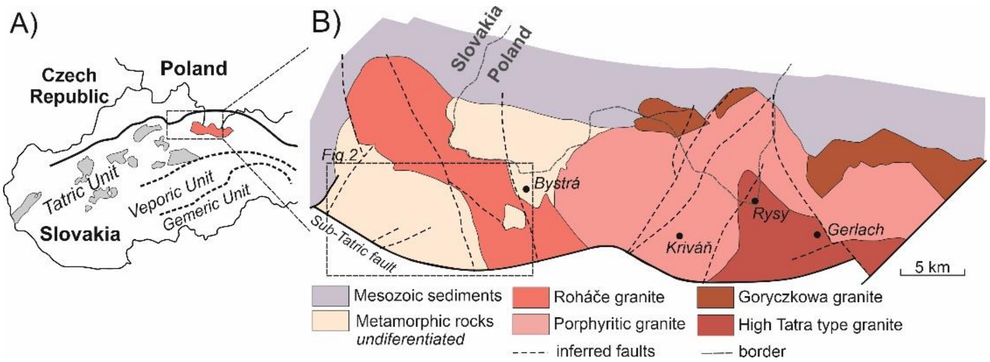

Figure 1. A) Location of the Tatra Mountains within the Western Carpathians. B) A simplified map of the Tatra Mountains showing the four main types of granites and the metamorphic envelope of the Western Tatra Mountains (compiled after Janák et al., 2022; Burda et al., 2021; Gawęda, 2007). The dashed rectangle indicates the position of the map presented in Fig. 2.

Meso- and microscale structures indicate a polyphase Variscan and Alpine deformation history of the crystalline basement in the Western Tatra Mountains. The earliest deformation event, D1, reflects the Variscan juxtaposition of metamorphic units (Fig. 2; Fritz et al., 1992; Janák et al., 1999). Microstructures associated with (i) dynamic recrystallization of feldspar porphyroblasts and (ii) diffusion-controlled formation of quartz lineation (Janák et al., 1999) suggest deformation under high-temperature conditions. D1 kinematics point to top-to-S/SE shearing, which is related to the thrusting of the Upper Unit over the Lower Unit, resulting in the development of an inverted metamorphic sequence. In the Upper Unit migmatites, D1 deformation is locally expressed by isoclinal, south-vergent folds with sub horizontal axial planes. D1 shear zones have been proposed as weak planes facilitating melt migration, contributing to the emplacement of syn-orogenic granitic sheets (Burda & Gawęda, 2009). The D2 deformation phase is attributed to late-Variscan orogen-parallel extension in an east-west direction (Janák et al., 1999; Ludhová & Janák, 1991). Locally, the D1 lineation in migmatites is transposed to biotite + sillimanite D2 lineation, which is associated with ductile top-to-E shearing. Similar brittle-ductile shear zone kinematics in the marginal parts of the granite pluton and metamorphic rocks near the contact have been reported by Kania (2015). The D3 and D4 events represent Alpine-age brittle deformation. The D3 event is characterized by NE-SW trending shear zones (Fritz et al., 1992; Nemčok et al., 1993) with top-to-NW shearing, corresponding to Cretaceous thrusting of sedimentary nappes over the crystalline basement. The final D4 event is linked to the uplift of the Tatra massif, accompanied by extension and predominantly sinistral oblique-normal slip faults during the Neogene. The southern flank of the Tatra Mountains was uplifted along the Sub-Tatric Fault (Fig. 1) during the Neogene at 22–14 Ma (Śmigielski et al., 2016). The structural and microstructural complexities of the Tatra crystalline basement have been most recently documented by Jurewicz and Bagiński (2005) and Kania (2014, 2015), though these studies offer somewhat differing interpretations of the region's structural evolution.

A more detailed description of the Lower and Upper units including geochronological and petrological constraints is given below.

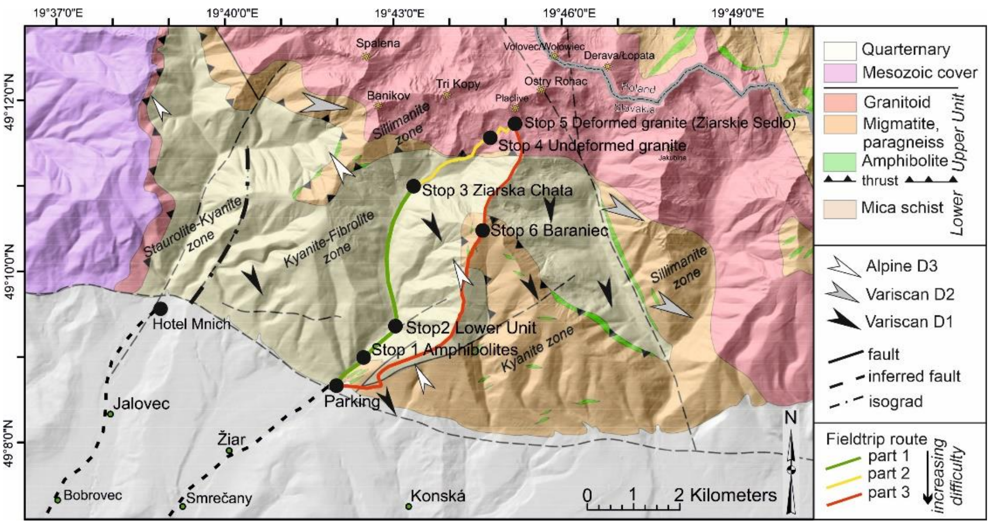

Figure. 2. Simplified geological map of the southern flank of the Western Tatra Mountains. The extent of the Lower Unit, Upper Units, and Roháče granite, as well as tectonic boundaries, are modified after Nemčok et al. (1994) and Lufhova and Janák (1999). Metamorphic zones are based on Janák et al. (1988).

Geological transect

Stop no.1 Garnet-bearing amphibolites of the Upper Unit

(49.150465°N; 19.707194°)

The starting point of the fieldtrip is at the parking lot located at the mouth of the Žiarska valley (Fig. 2). We will hike up the valley about 600 m passing by the outcrops of amphibolites near the historical mining site of Medvedia štôlňa. The outcrop of interest is located about 250 m higher up the valley, on the right-hand side about 30 m above the trail. This klippe is built of garnet-bearing banded amphibolite at the lowermost levels of the Upper Unit (kyanite zone sensu Janák et al., 1996, 1999). Felsic layers within the banded amphibolite show trondhjemetic to tonalitic composition. The origin of this layering is a matter of discussion. According to Janák et al. (1996) it could be an effect of partial melting of precursor, potentially a high pressure metabasite. Indeed, rare garnet and clinopyroxene-bearing (retro-eclogitic) lenses occur within the banded amphibolites. All the aforementioned mafic lithologies are hosted by kyanite-bearing metasedimentary rocks and orthogneisses. As mentioned above, several attempts to date the inferred HP metamorphism have not given an unequivocal answer, but the age of this event can be constrained to 369-354 Ma. The following lower pressure metamorphic evolution involved initial partial melting at temperature exceeding 730°C and pressure of 1.2 GPa, which was followed by further dehydration melting at 1.0-0.6 GPa and 750-800°C based on geothermobarometry of kyanite-bearing paragneisses and migmatites (Janák et al., 1999; Moussallam et al., 2012). The P-T conditions of 0.9–0.7 GPa and 740-860°C were derived for amphibolites in the Polish part of the Western Tatra (Gawęda et al., 2018). The age of partial melting in migmatites was estimated to 347-340 Ma based on U-Pb dating of zircon and monazite in the leucosome (Moussallam et al., 2012). Detailed in situ multi-isotope and elemental determinations on zircon (SIMS U-Pb dating, oxygen isotope and REE analyses) of amphibolites at this locality revealed three distinct zircon forming events: igneous zircon growth at ca. 498 Ma (Middle/Late Cambrian) and two phases of amphibolite-facies metamorphism at ca. 470 Ma (Early Ordovician) and at ca. 344 Ma (Early Carboniferous). The Lower Paleozoic ages are thereby interpreted to be a first record of the Cenerian Orogeny in the Western Carpathians (Burda et al., 2021).

Stop no.2 Mica schists of the Lower Unit

(49.155139°; 19.715449°)

We will hike up the valley about 1 km passing by the outcrops he Lower Unit exposed as a tectonic window of up to 1000 meters vertical distance (Fig. 2). It consists predominantly of mica schists containing garnet, staurolite, kyanite, fibrolitic sillimanite biotite, muscovite, plagioclase and quartz. These metapelites alternate with quartz-rich metapsammites. Based on such characteristic lithology, Kahan (1969) proposed that these rocks were former flysch sediments. Moving from the west to east, an increase in metamorphic conditions between the staurolite-kyanite and kyanite-sillimanite (fibrolite) zones is marked by the staurolite-out isograd (Fig. 2; Janák, 1994; Janák et al., 1988, 1999). Staurolite is an index mineral mainly in the Jalovecka valley whereas kyanite and fibrolitic sillimanite are characteristic for the staurolite-kyanite and kyanite-fibrolite zones. Retrograde minerals include chlorite, margarite and chloritoid in some fluid-altered samples. Fe-Ti oxides are represented mainly by rutile, ilmenite and titanite, with rutile often partially replaced by ilmenite. Apatite, zircon, monazite, and tourmaline occur as accessory minerals.

Monazite has been used to date metamorphism in the Lower Unit metapelites. Y, Nd, Ca, and Th compositional maps show that some monazite grains display simple core-rim zoning, while others show a homogeneous distribution of these elements throughout the grains (de Doliwa Zielinski et al., this issue). The LA-ICP-MS U-Pb geochronology was applied to date monazite from six samples. The calculated individual dates vary slightly between the samples and within a single sample, but no clear correlation was observed between the ages and the distribution of mapped elements. However, age differences were found depending on the sample location. Monazites from the staurolite-kyanite zone yielded ages of 318 ±6 to 323 ±6 Ma, while those from the kyanite-fibrolite zone gave ages of 330 ±3 to 335 ±6 Ma.

Stop no.3 Žiarska Chata

(49.181218°; 19.719439°)

We will follow the road up the valley, and after 3 km, we will reach Žiarska Chata, located in the upper part of the Lower Unit. In the event of bad weather preventing further hiking, we will return to the parking area and visit an additional outcrop of Upper Unit rocks.

Stop no.4 Undeformed Roháče granite

(49.193175°, 19.748474°)

We will follow the green trail from Žiarska Chata to Žiarske Sedlo, covering a distance of 3 km with an elevation gain of approximately 620 meters. Approximately 200 meters below the Žiarske sedlo we observe the first outcrops of the Roháče granite (Fig. 3). In this part of Western Tatra Mountains, Roháče granite forms a NW-SE trending, sill-like intrusion accommodated within the migmatites and paragneisses of the sillimanite zone of the Upper Unit (Janák et al., 1999). The medium- to coarse-grained porphyritic granite is primarily composed of K-feldspar phenocrysts, alkali feldspar, quartz, biotite, and muscovite, with minor amounts of ilmenite, fluorapatite, zircon, monazite, and allanite (Kohút & Janák, 1994; Gawęda et al., 2016). In this location, the granite exhibits an igneous porphyritic texture, and in certain areas, it shows an igneous foliation characterized by the parallel alignment of K-feldspar phenocrysts. The granite displays low- to no-strain fabric; however, the strength of the fabric increases on a meter-scale as one moves upward towards the Žiarske sedlo.

The Roháče granite has a peraluminous composition and fits within the calc-alkaline to high-K calc-alkaline suite (Kohút & Janák, 1994). The granitic magma was emplacement at approximate conditions of 800°C at 5–7 kbar (Gawęda, 2007), which is consistent with the estimated P-T conditions of migmatisation of the Upper Unit metasediments (Janák et al., 1999). LA-MC-ICP-MS U-Pb dating of seven zircon grains yielded a concordia age of 360 ±5 Ma, which is interpreted as the crystallization age (Gawęda et al., 2016). A recent geochronological study of undeformed granite exposed on the Plačlivý Roháč, and Príslop peaks using SIMS U-Pb geochronology technique, yielded 345 ±2Ma and 346 ±2Ma, respectively.

Interestingly, a sample of granite collected at the Baníkov summit yielded a significantly older age of ca. 352 ±2Ma, pointing towards internal diversification of this tongue-like intrusion. In fact, such a progression aligns well with a general model of a Himalaya-like megastructure, with a progressively younger granitic sheets in the central part of the upper tectonic unit.

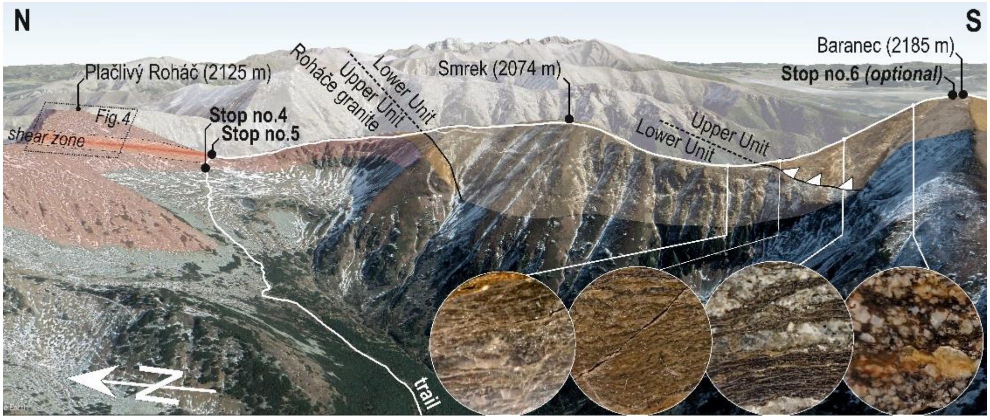

Figure 3. N-S panorama from Plačlivý Roháč to Baranec. Different lithologies, tectonostratigraphic units, and tectonic boundaries are modified after Nemčok et al. (1994) and overlain on a Google Earth 3D terrain model. Inset photos of hand-sized samples collected on the northern slope of Baranec illustrate lithological changes approaching the boundary between the Lower and Upper Units. The width of the inset photos is 3 cm.

Stop no.5 Deformed Roháče granite

(49.193279°; 19.750190°)

The Roháče granite locally displays an oriented fabric, which is more pronounced in the marginal parts of the granite body and in the host migmatites of the sillimanite zone (Figs. 2 and 3). This fabric is believed to be associated with synkinematic emplacement in an active shear zone during the D1 top-to-S/SE ductile deformation (Fritz et al., 1992; Janák et al., 1999). However, lineations within the marginal parts of the granite pluton and higher levels of the Upper Unit indicate top-to-E shearing, which is characteristic of the late-Variscan D2 orogen-parallel extension (Janák et al.,1999). In the granite, the D1 stretching lineation is defined by mica grains and quartz + feldspar aggregates, while the D2 lineation is predominantly indicated by biotite. K-Ar dating of white mica separates from the northern Roháče granite envelope yields an approximate cooling age of 305 ± 11 Ma (Deditius, 2004). Similar ages, ranging from 330 to 300 Ma, obtained from ^{40}Ar–^{39}Ar dating of white mica from both the granite and migmatite (Maluski et al., 1993; Janák and Onstott, 1993; Janák, 1994), confirm the postkinematic cooling stage and provide a lower bound for the timing of the late-Variscan D2 deformation event. The Alpine D3 deformation is predominantly characterized by top-to-NW shearing (Fritz et al., 1992).

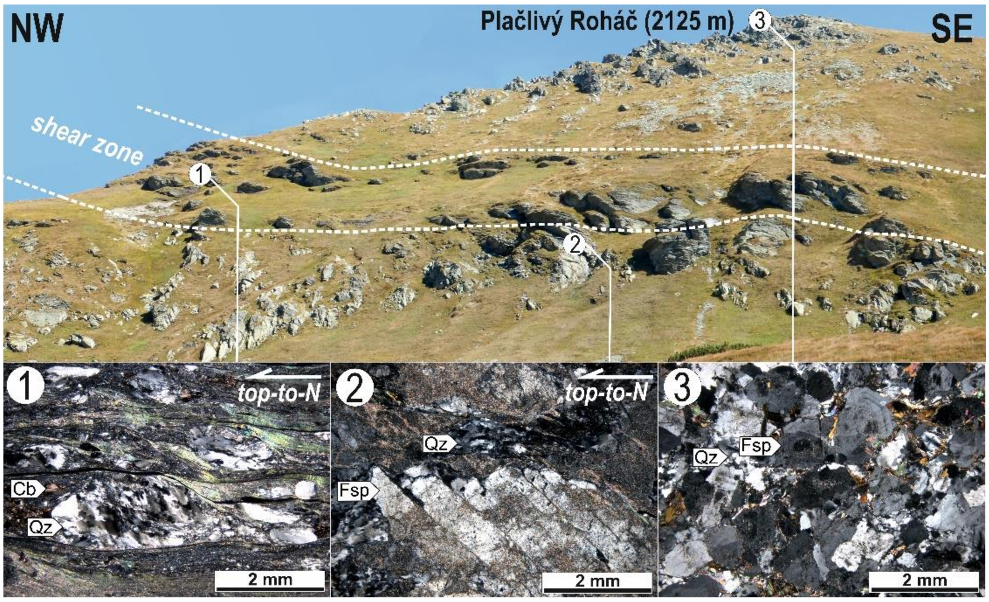

Figure 4. NW-SE panorama of Plačlivý Roháč showing a bottom-up transition from undeformed granite, through the top-to-NW shear zone, to undeformed granite at the top. Crossed-polarized light photomicrographs display typical microstructures of: (1) mylonite with ductilely deformed quartz porphyroblasts in a fine-grained matrix; (2) brittle deformation of feldspar in protomylonite; and (3) undeformed Roháče granite.

As we approach stop no. 4, located in the Žiarske sedlo, we observe increasing strain in the granite. This strain is manifested by the formation of foliation and the presence of C-S fabric, predominantly highlighted by fractures at the outcrop scale, as well as sigmoidal feldspar and quartz grains. The granites in the Žiarske sedlo represent the western termination of a top-to-NW shear zone located at the base of the Plačlivô peak (Figs. 3 and 4). Strain variation is evident within a ~40 m thick zone where the granite transitions from low- and medium-strain, showing the initial stages of mylonitization, to proto- and ultramylonites. Protomylonites from the base of the shear zone exhibit brittle-ductile deformation. Alkali feldspar primarily shows microstructures associated with brittle deformation, where porphyroblasts fracture along the cleavage planes and fragments are reoriented consistently with the shear sense (Fig. 4). Quartz is affected by crystal-plastic deformation, as indicated by the formation of subgrains and undulous extinction (Fig. 4). In the mylonites and ultramylonites, alkali feldspar is rounded and shows signs of incipient recrystallization along the rims. Quartz forms either highly strained sigmoidal porphyroblasts or recrystallized fine-grained matrix, indicating ductile deformation. White micas of fish-like shape are largely recrystallized, and carbonates are readily observed in the pressure shadows of quartz and feldspar porphyroblasts. According to geological map of Nemčok et al., (1993) similar shear zones are predominantly NNW-SSE trending and can be traced within a granitic part of the crystalline basement exposed west of Roháče.

Notably, while hiking from the Žiarske sedlo to the peak of Plačlivô, one may encounter a horizon of strongly brecciated granite with black veins. The ultrafine-grained material within these veins, their dark color and characteristic offshoots suggest these to be pseudotachylites. Similar pseudotachylites from the Gerlach area in the High Tatra Mountains (Petrík et al., 2003) yielded a broad range of Alpine ^{40}Ar–^{39}Ar ages, with a peak around 30–50 Ma (Kohút & Sherlock, 2003), suggesting seismic activity related to the Paleogene uplift.

Stop no.6 (optional) Baranec - migmatites and retro-eclogites

(49.173586°; 19.741448°)

Participants feeling adventurous can follow the yellow trail heading south from Žiarske Sedlo to Baranec (Figs. 2 and 3), covering a distance of 2.5 km with an elevation gain of approximately 400 meters. The rocks exposed along the trail on Smrek consist of sillimanite-bearing mica schists of the Lower Unit, locally featuring meter-scale folds with gently NWW-dipping fold axes. Hiking along the northern slope of Baranec allows observation of strain variations in the lower section and an increasing degree of migmatisation in garnet-bearing paragneisses further up the profile (Fig. 3). Meter-scale outcrops of retro-eclogites and amphibolites are exposed on the southern side, below the peak of Baranec. These rocks record isothermal decompression from 1.6 GPa to 1.0–1.2 GPa at 750–800°C, associated with retrograde re-equilibration and, locally, partial melting under granulite-facies conditions (Janák et al, 1996). U-Pb zircon dating of eclogite at this locality revealed ca. 367 Ma age for eclogite-facies conditions and c. 349 Ma for amphibolite-facies overprint (Burda et al., 2021). Continuing south on the yellow trail, participants will return to the starting point at the Žiarska Valley parking lot.

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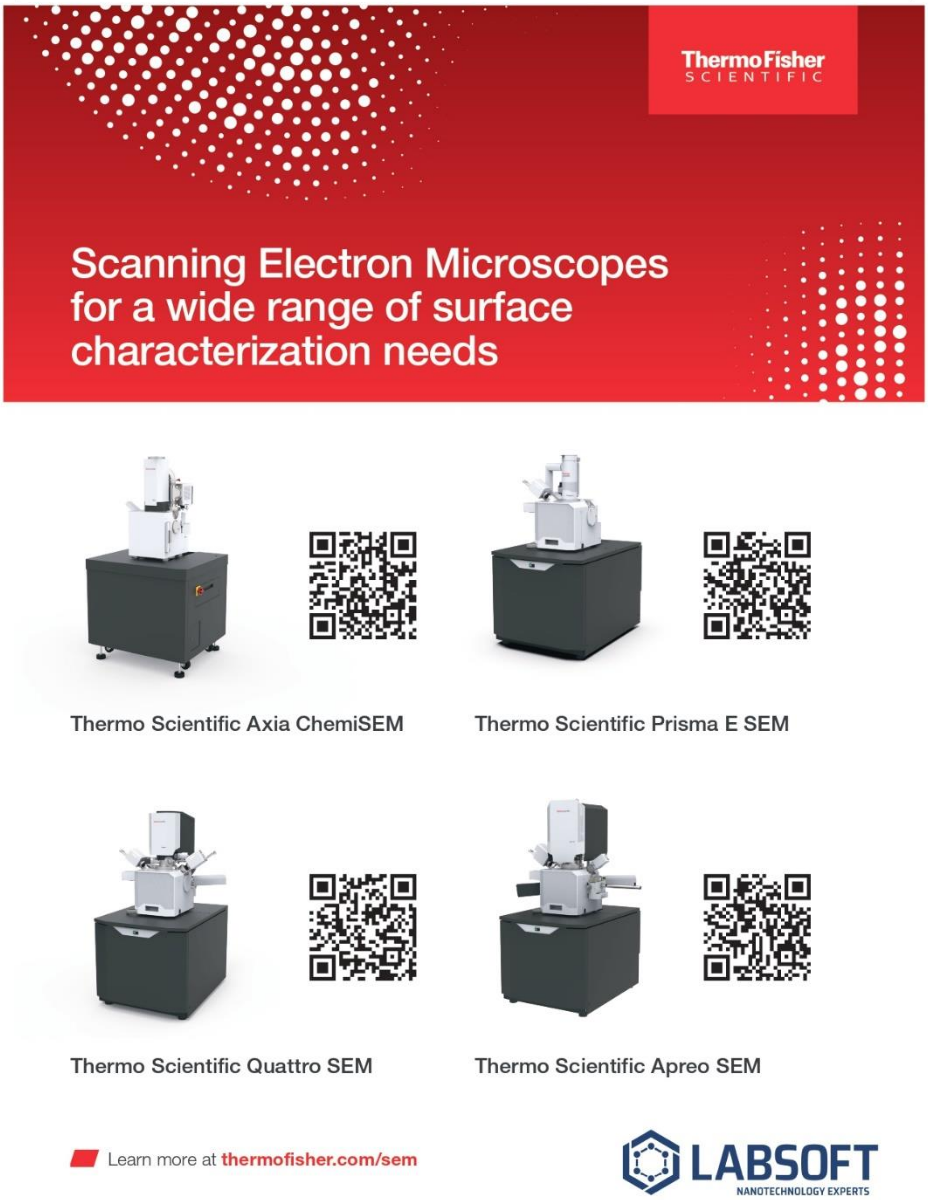
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Structure determination using high-quality X-ray powder diffraction data

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The determination of the crystal structure is a key element in the characterization of any new compound. In most cases, crystal structures are solved using single-crystal X-ray diffraction methods. However, not all compounds crystallize as single crystals of sufficient size and quality. An alternative is to use powder diffraction methods. For powder diffraction, a very important point for structural analysis is to obtain high-quality diffraction data. High-quality data are obtained using Rigaku instruments equipped with a rotating anode, Johansson monochromator and high-end detectors. The presentation will show examples of data collected with the SmarLab XE diffractometer and examples of structural analysis in SmartLab Studio II, including steps such as indexing, spatial group determination, crystal model determination and Rietveld method refinement.

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