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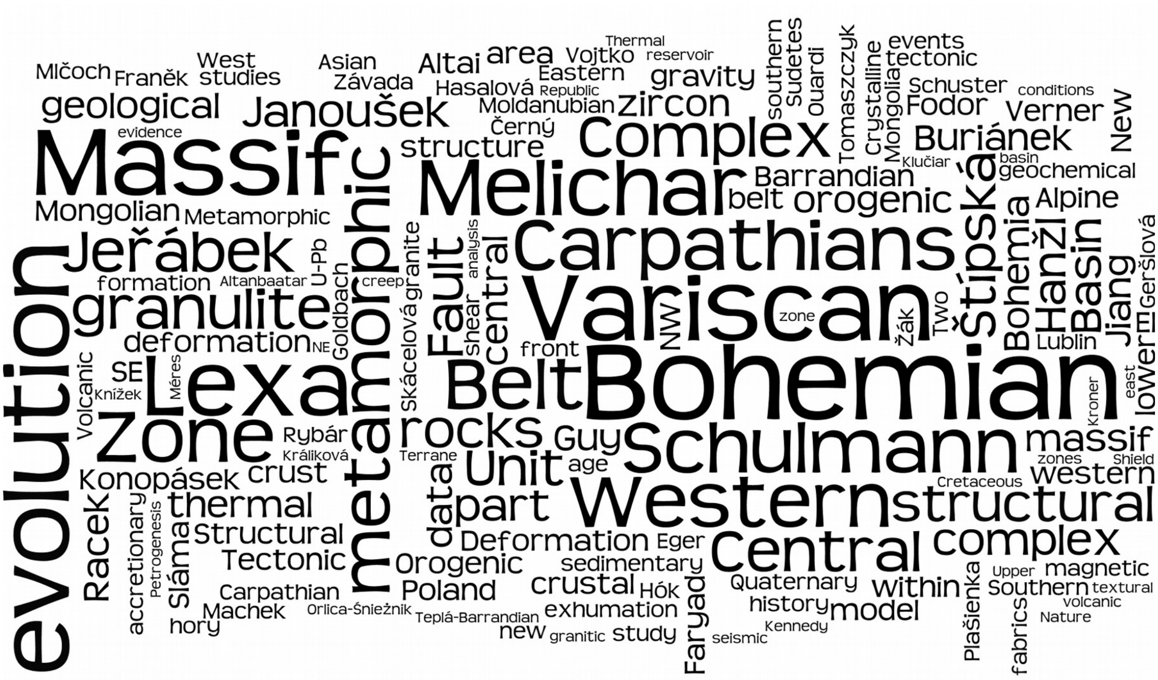

The meeting is organized by
Czech Geological Survey
Faculty of Science, Charles University in Prague

Organizing team
Pavlína Hasalová, Ondrej Lexa & Petr Jeřábek

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How and why non-marine bivalves record the growth and the collapse of the Variscan belt

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Palaeozoic non-marine bivalves (belonging to three extinct families, namely the Amnigeniidae, Myalinidae and Anthracosiidae) are found in deltaic, fluviatile and lake sediments throughout the Variscan belt and its foreland. The spatial and temporal distribution of the non-marine bivalves has been reconstructed based on an extensive search in the literature, initially fuelled by some field observations.

During the Devonian, the Amnigeniidae are restricted to the southern margin of the Laurussia supercontinent. During the Early Carboniferous (Tournaisian and Visean), Myalinidae and Anthracosiidae are found in a few places, then they invade all foreland basins during the Serpukhovian, Bashkirian and Moscovian (Namurian and Westphalian). Few of them are found in the intramontane basins during the Moscovian (late Westphalian). By contrast, almost all Kasimovian-Gzhelian (Stephanian) basins have their bivalve communities. These become rarer during the Permian.

To explain these changing patterns through time, we will first examine some biological aspects of the life cycle of the non-marine bivalves (taking into account the potential caveats of an actualistic approach), then discuss their link to the tectonic history of the Variscan belt. The main phase of growth of the Variscan belt occurred at the same time than the foreland basins were subsiding due to flexural loading. In these areas, eustatic sea-level fluctuations created large-scale but short-lived biotopes that were convenient for opportunistic species such as the non-marine bivalves. The mountain belt was drained by a few major rivers, some of them being colonized by the non-marine bivalves. Later on, the collapse of the Variscan belt was associated to a dynamic change of the drainage patterns inside the belt, allowing transient connections between lakes and rivers. Drying up of the climate by the Permian resulted in a severe reduction of the diversity of the non-marine bivalves, few of them surviving the end-Permian crisis.

Magnetic fabrics of the NE part of the Central Bohemian Plutonic Complex

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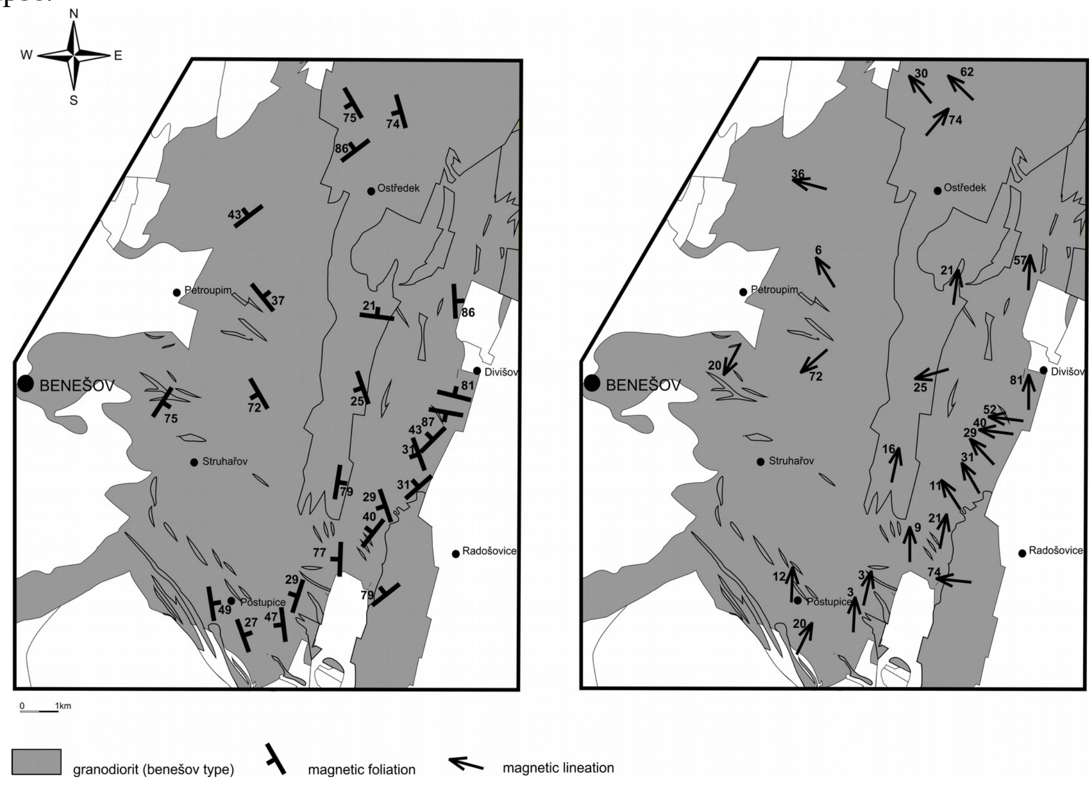
The study is focused on the NE margin of the Central Bohemian Plutonic Complex, Bohemian Massif, Czech Republic. Plutonic rocks from this area are known as “Benešov type” and they are usually represented by amphibole-biotite granodiorites.

Over 350 samples were taken using a portable drill at 26 sampling sites covering almost all study area. AMS (Anisotropy of magnetic susceptibility) data were used to characterize the magnetic fabric. These results were compared with mesoscopic structural observations and, at some sites, also with microstructures.

The AMS method showed several different magnetic fabrics and variations in the shapes of the AMS ellipsoid and the magnetic fabric intensity in the area. The degree of anisotropy varies from 1.033 to 1.132. The shape parameter T varies from medium prolate (-0.483) to strongly oblate (0.777). Most of samples have prolate ellipsoid of deformation. The value of shape parameter increases from east to west. Relatively low bulk magnetic susceptibility of measured samples (0.67×10^{-4}SI – 4.08×10^{-4}SI) suggests that the AMS signal is caused by paramagnetic minerals. Magnetic fabrics (Figure) are usually homogeneously oriented through the Benešov type. Magnetic lineations dip to the NW or N at low angels. Most of magnetic foliations dip to the W. AMS fabric in the Benešov type can be interpreted as deformation fabric of orogenic collapse.



Shear failure of rocks and creating their shear plane

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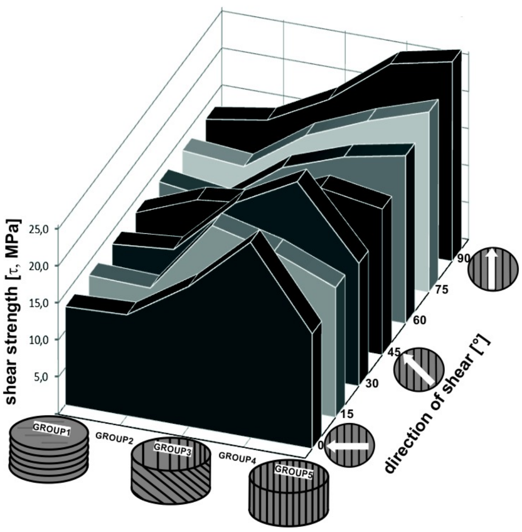
The study was focused on exploration of the shear strength of slate with distinguish planes of weakness, i.e. cleavage. Slaty cleavage represents the ability of rock to split into more or less parallel planes and disturbs the rock massif. The presence of these planes of weakness affects the strength and deformational behaviours of rocks and indicates asymmetric fracture of rocks and unpredictable strength behaviour.

Tests were carried out on the laminated slate with predetermined shear plane. This rock originates from “Bělá” quarry from the Moravo-Silesian Culm, Czech Republic. The oriented specimens were taken by manual drilling machine. The drilled specimens of slate were divided into five groups based on the different angle α between shear plane and cleavage Testing of each group was carried out in seven directions with an interval of 15°. The first direction which was called “zero” direction was perpendicular to the cleavage. Solids were tested at portable rock shear box assembly Matest A129.

Specimens confirmed anisotropic strength behaviour (Figure). Large variability of measured values of the strength was caused mainly by various dip of cleavage and by the direction of shear but in lesser extent. Two types of mechanisms of shear failure of specimens and creating their shear planes were distinguished (sliding vs. splitting). The first type was recognized for groups 1 a 2 (specimens with angle α = 0°–30°). These groups were characterized by lower values of shear strength and smoothed newly-formed shear planes, which are parallel to cleavage. It might have been caused by the parallel position of phylosilicates. These minerals reduce the friction ability of rocks and allow them to split. The other type, splitting, was recognised for group 4 (α=70°–80°). This group was characterized by high values of shear strength without visible newly-formed shear planes and the specimens were crushed during the test. It might be explained by dominant influence of friction ability of rock. The group 3 (α=45°) is considered to be a transitional group with lower values of shear strength and specimens were crushed during testing. Significant effect of the shear direction on the strength was demonstrated on the group 5, on the specimens with cleavage upright to the shear plane (Berčáková, 2014).

Berčáková, A., 2014. Shear strength of selected anisotropic rocks with cleavage. MS, master thesis. Masaryk University. Brno. Czech Republic. K-VZ-2014-BERČ.



Graphic plot showing values of shear strength of five groups of laminated slate (based on the different angle α between shear plane and cleavage) in seven directions of shear with an interval of 15°.

Tectonic applications of the local earthquake waveforms analysis in the West Bohemia/ Vogtland swarm area

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The West Bohemia/Vogtland earthquake swarm area is situated at the western edge of the Eger rift. It is known for its pronounced geodynamic activity with swarm seismicity and large-scale diffuse degassing of mantle-derived fluids. The seismicity is monitored by seismic stations of the WEBNET network, which has been operating for more than twenty years. Local earthquakes recorded by this network are concentrated to several focal zones with the prevailing number of events in Nový Kostel focal zone. The seismic records of events during 1997, 2000, 2008, 2011 and 2013 Nový Kostel seismic swarms as well as stronger events of the other focal zones give us the database for further investigation of this geodynamic region.

Apart from standard processing of data (P- and S-wave arrivals, localization and magnitude estimation of events), quality data enable detailed analyses of seismograms. Seismograms of local events display pronounced reflected and refracted waves both for P- and S-wave onsets and also split S waves. In addition, seismic signals show deviations from the simple 1-D upper-crust velocity model, indicating variations of P- and S-wave velocities, the v_P/v_S ratio variability, wave back-azimuth deviations and anisotropic behaviour of the area. Indicating these phenomena we try to give the accuracy to results of follow-up studies, comprising determination of geometry of active fault zone, focal mechanisms and full moment tensor estimation. Such information improves our knowledge about investigated tectonic structure of the whole geodynamic area monitored from the seismic rays.

We developed a new multi-azimuthal approach in data processing to increasing resolution of Moho and other secondary phases in the waveforms. Apart from the velocity structure and the source-receiver geometry, the waveforms are significantly affected by focal mechanisms of the earthquakes. Thus, the waveforms of earthquakes were grouped into clusters with similar focal mechanisms and clusters were processed separately.

The newly applied multi-azimuthal approach revealed details in the velocity structure of the crust/mantle transition at each station. Instead of a single interface with a sharp velocity contrast, the inversion indicates a reflective zone at Moho depths with one or two strongly reflective interfaces, which is in agreement with the lower crustal zone interpreted by previous investigations. The thickness of the zone varies from 2–4 km within the depth range of 27–31.5 km and is delimited by reflections from its top and bottom boundaries, sometimes with strong reflectors in-between.

Vavryčuk, V. & Boušková, A., 2008. S-wave splitting from records of local micro-earthquakes in West Bohemia/Vogtland: an indicator of complex crustal anisotropy. *Stud. Geophys. Geod.*, **52**, 631–650. doi: 10.1007/s11200-008-0041-z.

Hrubcová, P., Vavryčuk, V., Boušková, A. & Horálek, J., 2013. Moho depth determination from waveforms of microearthquakes in the West Bohemia/Vogtland swarm area. *J. Geophys. Res*, **118**, 1–17. doi: 10.1029/2012JB009360.

Superimposed Variscan granite bodies in the Tribeč-Zobor Tatric unit: petrological and structural evidence

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Recent geological maps suggest a heterogeneous, vertical and horizontal zonal structure of the granite massif in the Tríbeč-Zobor Tatric Unit (Ivanička *et al.*, 1998, Bezák *et al.*, 2011). The vertical zonation is expressed by the occurrence of coarse-grained granitoids (granodiorites, tonalites) in the lower part of the granite massif, whereas the top is formed by a fine-grained strongly altered granite type. The fine-grained altered granites are located mainly along the axial ridge zone of the Tribeč Mts. locally containing nests or small cross-cutting bodies of leucocratic granites. The horizontal zonality is observed within the area of S- and I-type granites: the S-type is located mainly in the northwestern part of the mountains, the southeastern part is built by the belt of the I-type (Petrík & Broska, 1994). The latter type was dated by SIMS as Devonian/Lower Carboniferous (365–360 Ma, Broska *et al.*, 2013) and interpreted as subduction-related, originated in an arc environment within the Galatian superterrane (an assemblage of Gondwana derived fragments). According to monazite datings the S-type granites have a similar age and their formation may have been was facilitated by the I-type magmatism. Generally it could be stated that the Late Devonian to early Carbonifeous calc-alkaline I-type granitoids in the Western Carpathians are marker of an early Variscan active margin. A later, vast magmatic activity characterstic for the European Variscides was associated with mantle heat flow caused by slab break-off process occurring ca. 330 Ma ago (e.g. durbachite formation). The final period of the voluminous magmatic activity dated in range 325–310 Ma created the Saxo-Danubian Granite Belt which represents a response to a post-collisional detachment of lithospheric mantle below the south-western sector of Bohemian massif (Finger *et al.*, 2009). This distinct Variscan magmatic episode in central Europe can be correlated with ages obtained by monazite datings in the Tribeč ridge zone in altered granites giving ca. 330 Ma. Such data have also been obtained from leucocratic granites, which intruded the altered granite mass. This 330 Ma record from Missisipian/ Pensylvanian boundary in the Tribeč Mts. (Prototatricum) can be directly correlated with mantle-induced heating in Variscides producing in many places K-rich granites. In the Tribeč Mts. the weak 330 Ma magmatic activity probably reflects thrusting of the Prototatric unit accompanied by increased fluid activity, which altered the granites in the greenschist faces. Now they are positioned along the ridge zone of the Tribeč Mts. Tatric stacking in the Tribeč Mts. is recorded also in deep geological structure by seismic and magnetotelluric measurements. The juxtaposition of two different granitic blocks (the corse-grained tonalite in bottom and the altered granite in the upper part) of Missisipian/Pensylvanian age indicate on the one hand the tectonic complexity of the Tatric unit and on the other hand a spatial separation of the Prototatricum (which lacks the voluminous 330 Ma magmatism) from the Saxo-Danubian Granite Belt in Variscan realm. Moreover, in the Tribeč-Zobor block also the presence of crystalline basement of the Fatric nappe system can be recognised, represented by strongly mylonitised granites (locality Čierny Hrad). In these granitoids monazite datings showed also the Alpine crystallization. A large lazulite mineralisation in Lower Triassic quartzites rimming the Tribeč granite massif (Uher *et al.*, 2009) is also a strong indication of Alpine overprinting these granitoides.

Tectono-metamorphic evolution of western part of the Tauern Window, Eastern Alps

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The Tauern Window in the Eastern Alps represent a tectonic window, where Penninic continental units and overlying Piemontais oceanic units crop out from below the Austroalpine crystalline nappes. The window is formed by Subpenninic nappe system composed of Variscan basement (Zentralgneiss) with Mesozoic cover sequences overlain by Penninic nappes. The studied nappes were previously recognized as Lower and Upper Schieferhülle and their PT conditions of up to blueschist facies were determined by Selverstone (1988, 1993).

Our detailed structural and petrological study focused mainly on tectono-metamorphic evolution of different nappes. The Zentralgneiss cover sequences consist mainly of schists, amphibolites and quartzites with originally subhorizontal to gently westward dipping main metamorphic foliation. This dominant fabric was later affected by D_2 and D_3 deformation stages that are associated with folding and formation of axial-planar cleavage. D_3 is preserved mainly in the W part of studied area. The overlying Penninic nappes are composed of deformed greenschists, micaschists and marbles, which are affected by large scale open folds associated with D_2.

The metamorphic PT conditions were estimated by using the phase equilibrium modelling in software package Perple_X (Connolly, 2005) and chemical composition/zoning of garnets, which are mostly syn- to postkinematic to the formation of the main deformation fabric in the studied area. The compositional zoning in garnets revealed an overall prograde PT evolution with PT increase of up to 4.5 kbar and 70°C associated with the formation of main metamorphic foliation.

The structural and petrological record show the relation of nappe evolution and unroofing of the complex in the Tauern Window similar to that described by Jeřábek *et al.* (2012) in the West Carpathians. The EW stretching and prograde metamorphic evolution in the studied area is associated with burial, while exhumation is associated with formation of subhorizontal cleavage and dip-slip kinematics towards W which is in contrast to previous studies.

Jeřábek, P., Lexa, O., Schulmann, K., Plašienka, D., 2012. Inverse ductile thinning via lower crustal flow and fold-induced doming in the West Carpathian Eo-Alpine collisional wedge. *Tectonics* **31**, 5, doi 10.1029/2012TC003097.

Selverstone, J., 1988. Evidence for east-west crustal extension in the Eastern Alps: implications for the unroofing history of the Tauern Window. *Tectonics* **7**, 87–105.

Selverstone, J., 1993. Micro- to macroscale interactions between deformational and metamorphic processes, Tauern Window, Eastern Alps. *Schweiz. Mineral. Petrogr. Mitt.*, **73**, 229–239.

Petrogenesis and emplacement of the Carboniferous Sag-say Massif in the SE Mongolian Altai

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Sag-say Massif intruded the low-grade metavolcanosedimentary complex of the Cambrian Tugrug Fm. in the Sag-say river valley SW of Tsogt soum (SE Mongolian Altai). This oval body (~9 × 12 km) is composed mainly of amphibole monzogabbros to quartz diorites, biotite to amphibole–biotite syenites to monzonites. It is intruded by anatectic two-mica granites along the W rim. The abundant MME enclosed by syenites to monzonites are interpreted as an evidence of vigorous magma mingling and mixing.

The newly obtained LA ICP-MS zircon ages for two samples of monzonites revealed emplacement ages of 307±1 Ma and 309±2 Ma, respectively. They have zircon ε_{Hf}(t) values varying from 2.4 to 11.6. One gabbro body gave zircon U-Pb age of 322±2 Ma with positive zircon ε_{Hf}(t) values of 7.4–11.5, suggesting juvenile magma source.

While the slightly peraluminous granites (SiO_2 = 74.8–75.2 wt. %) are subalkaline, the dominant metaluminous, ultrabasic to intermediate plutonic rocks (SiO_2 = 41.4–65.8 wt. %) are mainly alkaline. The granites show HREE-depleted REE patterns (La_N/Yb_N = 28.3–30.7) with slightly negative Eu anomalies (Eu/Eu* = 0.8–0.9). In contrast, the remaining rocks display relatively weak LREE/HREE enrichments (La_N/Yb_N = 4.3–17.5) and no or positive Eu anomalies (Eu/Eu* = 1.0–1.6). The more basic types show an OIB-like chemistry, and all rock types share a within-plate geochemical signature (Th/Hf = 0.3–2.9, Th/Ta = 0.5–4.4).

According to calculated P–T conditions, we propose three main stages in the Sag-say Massif evolution. The early cores of amphibole crystals (pargasite, Si = 5.74–5.95; X_{Mg} = 0.59–0.71) from gabbro started to grow at >1000°C and 0.8–0.9 GPa (based on the thermobarometer of Ridolfi *et al.*, 2010). The ensuing magma mixing with crustal melts and final crystallization of gabbro occurred at similar P–T conditions (740–830°C and 0.5–0.6 GPa) as partial melting of migmatite xenoliths in the Sag-say Massif (736±74°C and 0.6±0.2 GPa; calculated with THERMOCALC, Holland & Powell 1998). The P–T conditions of the Sag-say Massif final emplacement calculated from quartz syenite (ca. 600 to 670°C and 0.4–0.5 GPa, Amp-Pl thermometer of Holland & Blundy, 1994 and Amp barometer of Anderson & Smith, 1995) are consistent with the mineral assemblage in the contact aureole (cordierite-biotite and biotite-chlorite schists).

Anderson, J. L. & Smith, D. R., 1995. The effects of temperature and fO_2 on the Al-in-hornblende barometer. *American Mineralogist,* **80,** 549–559.

Holland, T. & Blundy, J., 1994. Non-ideal interactions in calcic amphiboles and their bearing on amphibole-plagioclase thermometry. *Contributions to Mineralogy and Petrology*,**116**, 433–447.

Holland, T.J.B. & Powell, R., 1998. An internally consistent thermodynamic data set for phases of petrological interest. *Journal of Metamorphic Geology,* **16**, 309–343.

Determination of thermal diffusivity of sea sediments from temperature time series

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The propagation of thermal energy through sea sediments following temperature variations of the sea water above is dependent on the sediments thermal diffusivity. Traditional in situ measurement methods of thermal diffusivity require the knowledge of sediments specific heat capacity as well as the density to calculate the thermal diffusivity from thermal conductivity, both specific heat capacity and density are not easy to obtain in situ .The method presented here requires only a profile of sediment temperatures over time. A temperature time series was obtained in sea sediments located on the continental margin off western Svalbard using an array of 8 temperature sensors and a data logger (Feseker *et al.*, 2012). The sampling interval was 10 seconds over a measurement period of 10 days. The device recorded temperature data up to a sediment depth of 36 cm with 6 cm depth intervals. Inverse modeling of propagating temperature differences yield a thermal diffusivity of about 4.8×10^{-7} m^2 s^{-1}. Reported values are in good agreement with calculated thermal diffusivity (von Herzen & Maxwell, 1959) from thermal conductivity measured in the same area (unpublished data). The results could improve the modeling of the stability of gas hydrates located on the continental margin (Thatcher *et al.*, 2013) in response to increasing bottom water temperatures (Westbrook *et al.*, 2009).

Feseker, T., Wetzel, G. & Heesemann, B., 2012. Introducing the T-Stick: A new device for high precision in situ sediment temperature profile measurements. *Limnology and Oceanography: Methods,* **10**, 31–40.

von Herzen, R. & Maxwell, A., 1959. The measurement of thermal conductivity of deep-sea sediments by a needle-probe method. *Journal of Geophysical Research,* **64**, 10, 1557–1563.

Thatcher, K. E. et al., 2013. Methane release from warming-induced hydrate dissociation in the West Svalbard continental margin: Timing, rates, and geological controls. *Journal of Geophysical Research: Solid Earth* **118**, 22–38.

Westbrook, G. K. et al., 2009. Escape of methane gas from the seabed along the West Spitsbergen continental margin. *Geophysical Research Letters,* **36**, 15–16, L15608; doi:10.1029/2009GL039191

Microstructural and anisotropy of magnetic susceptibility records of a granite intrusion in Bohemian massif (Central Sudetes, Variscan orogenic belt)

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In the Bílá Voda valley, in western Sudetes, several magmatic bodies elongated in NE–SW direction intruded the strongly folded Snieznik Metamorphic Unit. The major perspective of our study is to understand the emplacement conditions and fabric development in these sheet-like bodies of granite during progressive transposition of the metasedimentary host rocks from S_1 fabrics shallowly dipping to the SE to subvertical NE–SW trending S_2 fabrics. In the host rock lithologies around the major map-scale granite bodies, numerous small sills of granite up to 1m thick show open to isoclinal folds concordant with the S_1 fabric of the host rock metasediments. Locally, granite sheets crosscut the host rock fabric at low angles to the S_2 axial fold cleavage. Succession of deformation events and rheological properties of the granites will be addressed by means of microstructural analysis of deformation mechanisms for quartz and feldspar (bulging, subgrain rotation and grain boundary migration) in different parts of the largest granite sill. The anisotropy of magnetic susceptibility (AMS) record throughout the major sill and several small scale granite sheets will be critically analyzed for superposition of different deformation events (e.g. corresponding to S_1 and S_2 in the host rocks) and later subsolidus overprint. Preliminary results suggest that the magmatic and submagmatic fabrics are present only in the middle part of the pluton. In addition, the crystal preferred orientation (CPO) of quartz will be analyzed to constrain in the major granite body the temperature gradient and the deformation gradient respectively increasing and decreasing from the edges to the center of this body.

Deformation of Ordovician sedimentary rocks, Prague Synform, Barrandian, Czech Republic

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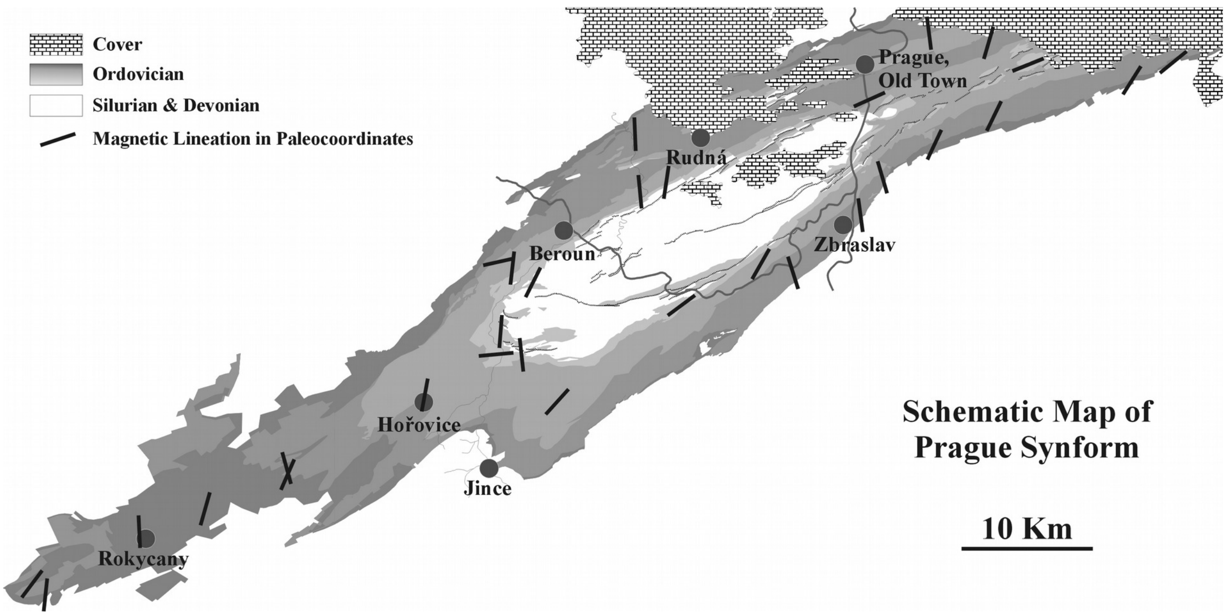
Sedimentary rocks in Prague Synform were significantly affected by deformation during variscan orogeny. The Silurian and Devonian rocks were intensely folded and thrusted (Melichar, 2003). Unfortunately, deformation of the Ordovician rocks is not visible. Due to observations of internal fabrics of rocks, anisotropy of magnetic susceptibility (AMS) study was extensively used. Different types of AMS fabrics were found in the investigated area.

This study is focused on strain fabrics. Such fabrics are associated with different deformation episodes that affected the area. Essentially, there are two groups of strain fabrics related to different deformation scenarios in Prague Synform. These groups differ in the orientation of magnetic lineation in paleocoordinates (Figure). From that point of view, the AMS fabrics from the neighbour of Skřípel village are very important for understanding the complicated situation in Ordovician rocks. These results points out that each group of strain fabrics was originated during different deformation.

Melichar, R., 2004. Tectonics of the Prague Synform: a hundred years of scientific discussion. *Krystalinikum*, **30**, 167–187.



Schematic map of Prague synform. Magnetic lineations have orientation parallel to the axis of main folds in the synform or they are oriented in N–S direction.

Usage of magnetic studies in coastal paleoseismology, Mexican Pacific coast

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Subduction zone earthquakes can generate abrupt vertical movement of the seafloor or submarine landslide. Both can produce a tsunami wave that can hit coastal areas. Such waves transport material which is usually deposited on flat plains and in topofraphic depressions on the coast. From this point of view, lagoons are ideal environments where tsunami deposits can be preserved.

The studied sites were situated in lagoons on the active Mexican continental margin, where both storm and tsunami inundations can occur. Despite the fact that magnetic studies alone can’t help solving the question if the inundation sediment was deposited by a tsunami or storm event, they can significantly help to respond other important questions. Recently, the potential of magnetic proxies in marine inundation deposits studies is still under consideration and there are some methodological difficulties.

Our most recent results showed that: 1) magnetic studies may be useful to determine what material was the main source of magnetic minerals in sediments; 2) AMS can help to distinguish different hydrodynamical environments related to different layers; 3) primary sedimentary fabric in fine-grained lagoon sediments such clays may have developed lateral imbrication; 4) the lateral variability of AMS parameters can be significant and a test of horizontal variability in sedimentary beds should be performed before final interpretations; 5) In some specific cases AMS fabrics might help to determine flow direction of the tsunami and this might be a hint if the triggering actor was an earthquake or submarine landslide.

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Distinction of Variscan, Permo–Triassic and Alpine events in andalusite–biotite–sillimanite schists from Sopron area, W-Hungary

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Andalusite-biotite-sillimanite schists from Sopron area (W-Hungary) contain well-preserved relics of pre-Alpine mineral assemblages and therefor play a key role in the understanding of the metamorphic evolution of the easternmost part of the Austroalpine nappes. Pre-Alpine relics are found in three domains: sillimanite-plagioclase-K-feldspar-biotite rich layers, garnet porphyroblasts and andalusite porphyroblasts. However, these domains are separated from each other in space which gives large uncertainties in the reconstruction of the P–T path.

In order to distinguish different metamorphic events, we studied the submicron scale features of the rock and carried out Sm/Nd dating on garnet porphyroblasts and Rb/Sr dating on biotites, respectively. According to this, the oldest preserved mineral assemblage is represented by Ca-rich garnet cores, high Ti-biotite, sillimanite and plagioclase. Based on geothermobarometry, this mineral assemblage was formed at ca. 640°C and 0.9 GPa. According to a Sm/Nd isochron, calculated from whole rock and two garnet core fractions an age of 330.4±2.7 Ma was determined. This age corresponds to the Variscan peak. Following cooling and decompression to about 570 °C and 0.3 GPa resulted in the formation of Zn-bearing staurolite. During nearly isobaric heating during the Permo-Triassic event, staurolite started to decompose to form andalusite, Zn-bearing spinel and corundum. Close to the temperature peak at about 660°C sillimanite-K-felspar intergrowths were formed and melting occurred. During retrograde cooling to about 500°C perthites and antiperthites were formed. Subsequently albitic lamellae exsolved from the K-felspars in antiperthites and pure albite rims developed between host plagioclase and perthitic K-feldspar. Following the crystallization of melt pockets at the Permo-Triassic retrograde path, the remaining SiO_2-rich aqueous fluids caused different reactions in different domains. Hydration of sillimanite-K-feldspar intergrowths resulted in the formation of large muscovites with sillimanite inclusions. In andalusite porphyroblasts, new staurolite was formed at the expense of former decomposition products found as microinclusions in the outer rims of staurolite relics.

Garnet was produced in several reactions during the Alpine cycle. Mn-rich garnets were formed at the beginning of the prograde path at the expense of chlorite. In this stage, muscovite and ilmenite partly replaced large, pre-Alpine biotites with high Ti-content. At peak pressures staurolite and less Mn-rich garnet formed in equilibrium. Alpine staurolite overgrowths on staurolite and biotite relics within andalusite porphyroblasts may have formed during this stage as well. At the Alpine retrograde path, garnets with fluid and quartz inclusions formed from reaction of pre-Alpine biotites and aluminosilicates. Na- and Ca-bearing SiO_2-rich fluids interacted-with the rock during this stage, resulting in the formation of paragonite- and margarite-rich micas and kaolinite. During cooling retrograde Fe-Mg exchange occurred between garnet and biotite and at the late stages, submicron-scale Mg-rich biotite and kyanite replaced garnet along cracks. Scattering Rb-Sr biotite ages reflect disequilibrium of pre-Alpine domains and mineral phases formed during the Alpine event.

Geochemical and tectonic correlation of the Permian basalts from the Hronic Unit (Western Carpathians)

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The Western Carpathians orogen is build by granite - metamorphic rock complexes, covered by sedimentary sequences tectonically arranged into the nappe structures during the alpine orogenic events. Pre-alpine structures were tectonically arranged during the Miocene collision with contemporary intra-arc basin sedimentation. The Hronic Unit is one of the most spatially extended tectonic nappe structure in the Western Carpathians. The lithology of the Hronic Unit represent a record of volcanic and tectonic evolution of the parental sedimentary basin from the Upper Carboniferous to Upper Triassic, up to the Jurassic time. Volcanism operated in parental Hronic area as two main volcanic phases in the Lower and the Upper Permian with massive production of basalts and their pyroclastics. Petrographically they respond mainly to basaltic andesites and lesser basalts, trachybasalt, trachyandesites with acid aplites accessories. They were a product of within plate volcanism generally known as basaltic traps. The presented results show chemical systematics of the Hronic basalts obtained from different part of the Western Carpathians and their relationship to host sediments generated in time before and closely after cessation of volcanism. The chemistry of basalts depends on composition of mantle source, degree and type of melting, equilibration during melt percolation through peridotites and modification of melt in continental crust by MASH, AFC and FC processes, if basaltic magmas remain there. These processes affect chemistry of basalt as for REE-HFSE disequilibria or HFSE anomalies. REE-HFSE distribution is very sensitive to type of basalt origin as for collision $Nb/La_n<<1$, $\triangle Zr<0$, or extensional environment $Nb/La_n\geq 1$, $\triangle Zr\geq 0$ or degree of extension $LREE_n<HREE_n$ in parental volcanic area. Calculated HFSE anomalies of the lower and upper Permian Hronic basalts show systematic geochemical shift $Nb/La_n\rightarrow 1$, $\triangle Zr\rightarrow 0$ and $LREE_n>HREE_n$ toward $LREE_n\geq HREE_n$ indicate increasing degree of extensional tectonic in the Upper Permian, but with any suggestion of transition to oceanic rifting style. Comparing HFS-REE distribution of basalts from different regional occurrences, chemistry arranges basalts focusing to degree of extension, in order from southern part of Low Tatra Mts. “sLT” (low extension), next Malé Karpaty Mts. “MK” and northern part of Low Tatra Mts. “nLT” (high extension). It’s a geochemical scenario, but tectonic and sedimentary evolution is interestingly consistent with geochemical signals. In Malé Karpaty Mts., there are conglomerate beds, which underlie basalt effusions and suggest strong tectonic disturbance before start of volcanism, whereas in the “nLT” volcanism is pressed by sedimentation of a huge packet of Kravany beds (opening and deepening of basin). Tectonic situation after finishing of volcanism is also different in “MK” where erupted basalts were affected by erosion and flooded into the younger clastic sediments, whereas higher degree of rapid extension in nLT caused subsidence slip and basalts were buried immediately after their eruption (no basalt clasts observed). Presented results suggest eruption of the Permian Hronic basalts in different parts of parental basin as result of extension induced volcanism, rather as triggering by mantle plume. The geochemistry of basalts is consistence with extension and basin propagation. It suggest, that HFSE–REE system seems to be applicable as a geochemical extensionmeter.

Origin of columnar jointing and direction of cooling

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Columnar jointing has been studied since the first report of Giant´s Couseway in Scotland. This phenomenon was studied for centuries and many theories tried to explain its origin. The formation of igneous columnar joints is now reasonably understood. These joints, which result from thermal contraction during cooling of magma or lava flow, are of particular interest because they reflect the thermal history of a rock mass.

The symmetric natural fracture network is formed during the cooling of volcanic bodies. Usually, we may observe a variety of columnar shapes in the nature such as triangular, quadratic, pentagonal or hexagonal. However, the most common geometry is hexagonal. The reason is that hexagonal honeycomb-like arrangement of contraction cracks would maximize the area-to-fracture-length ratio and minimize the total crack area at the same time relive as much of the thermal stress as possible. That‘s why the hexagonal shape is the most common in the volcanic rocks.

The columns always grow perpendicularly to the cooling surface and the fracture pattern tends to be propagated from the surface towards the center of the volcanic body as it cools. The fractures have usually developed tensile cracks known as growth bands on their surface (Figure). The bands are the most significant features on the surface of the column; prolongation of the bands is oriented perpendicularly to the axis of the columns. Initial point showing where the tectonic band began to grow can be found thanks to the geometry of plumose structure. Different patterns of wrapping were recognized. Relationship between two bands on the same column side allows us to determine the direction of gradual cooling. Sometimes the bands are distorted due to irregular conditions. Special type of little ridges within the plumose structure has en echelon shape and it is known as twist-hackle.

a) Growth bands on the column surface; b) Plumose structure on the band surface.

AMS fabrics in the Upper Proterozoic metasediments of Barrandian

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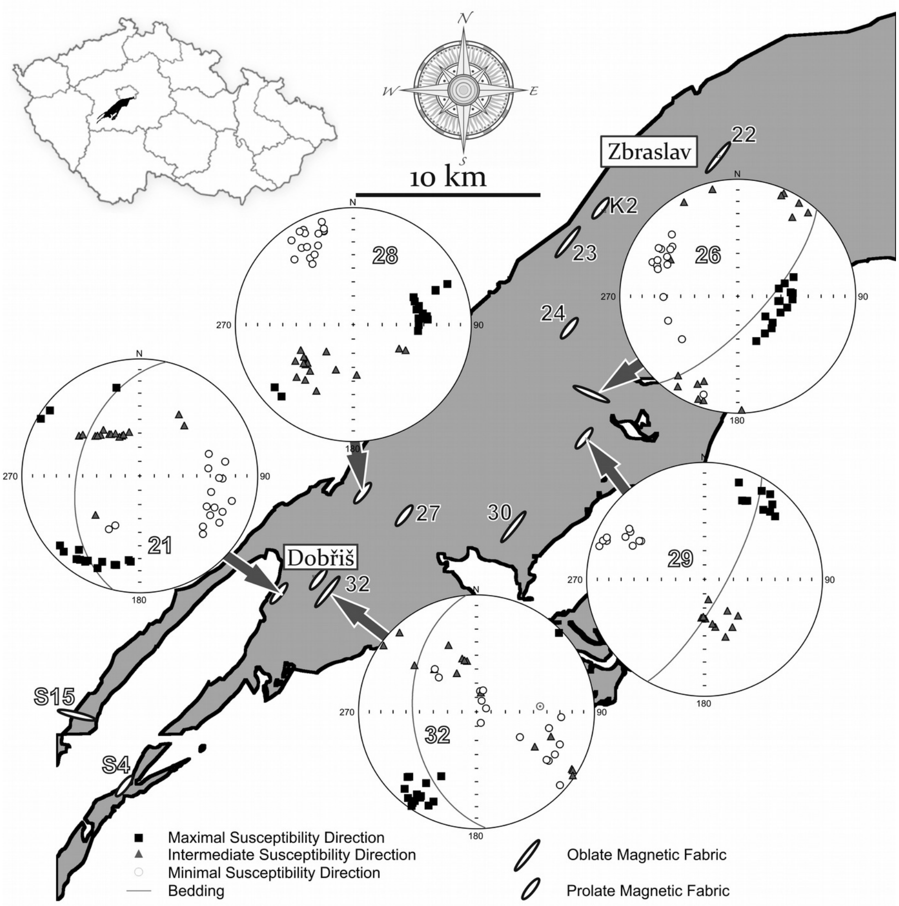
The work was focused on the Upper Proterozoic metasedimentary rocks, studies of their anisotropy of magnetic susceptibility (AMS). Research was held in Kralupy-Zbraslav and Štěchovice formations that are situated in Barrandian, Czech Republic. There is a 15–20 km wide and about 60 km long stripe among Prague, Dobříš, Přibram, Rožmitál pod Třemšínem and Nový Knín. About 220 oriented samples were collected by manual drilling machine from outcrops or in laboratory from oriented blocks. AMS of drilled cores was measured in AGICO laboratories Brno on MFK1 instrument.

In studied rocks were founded two types of AMS fabrics (Figure). Types are caused by different litology: fine-grained sediments are associated with oblate fabric with dominated magnetic foliation (bedding), however the coarse-grained ones generate prolate fabric indicating strain. Two orientations of AMS fabrics, found on studied area, are presumably called by different deformations. The most common deformation is varisian, AMS axis are oriented NW–SE. This deformation was caused by massive intrusions on NE of region. The second AMS fabric of unknown origin is oriented NE–SW. During our studies was found one site (28) with inverse fabric. This may be caused by ankerite or siderite and need further investigation.



Two Variscan metamorphic events in basement rocks from the Moldanubian Zone (Bohemian Massif)

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Recent results of petrological studies on HP-UHPM rocks in the Moldanubian Zone of the Bohemian Massif; mainly, compositional zoning and solid phase inclusions in garnet from various lithologies enabled the establishing of a prograde history of the rocks which underwent subduction and subsequent granulite facies metamorphism during Variscan orogeny (Faryad *et al.*, 2013, Perraki & Faryad, 2014). It was shown that the HP-UHP metamorphism and their amphibolite-granulite facies overprint could be two separate processes that occurred in the Moldanubian Zone (Faryad *et al.*, 2015). In this contribution we present further evidence indicating that the granulite facies metamorphism occurred after the HP-UHP rocks had already been exhumed to different levels of the middle or upper crust. A medium-temperature eclogite that is part of a series of tectonic blocks and lenses within the amphibolite facies Monotonous unit contains preserved eclogite facies assemblage with prograde zoning garnet and omphacite that is partly replaced by a symplectite of diopside + plagioclase + amphibole. Garnet and omphacite equilibria and pseudosection calculations indicate that the HP metamorphism occurred at relatively low temperature conditions, reaching about 650°C and 2.0 GPa. The striking feature of the rocks is the presence of garnet porphyroblasts with fractures filled by granulite facies assemblages. They are represented by olivine, spinel, and Ca-rich plagioclase which occur as a symplectite forming two central, olivine-rich and marginal, plagioclase-rich zones. The olivine- spinel equilibria indicate temperatures of about 900°C. The overall textures, principally the preservation of eclogite facies assemblages support that the granulite facies overprint was a short-lived process as it was also documented earlier from the Moldanubian Zone (O´Brien & Vrána, 1995). The new results allow constraining of a geodynamic model suggesting exhumation of HP-UHP rock along the subduction channel with most of the granulite facies equilibration occurring due to heating by mantle derived magma in the middle and upper crust.

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Faryad, S. W., Kachlík, V., Sláma, J. & Hoinkes, G., 2015. Implication of corona formation in a metatroctolite to the granulite facies overprint of HP–UHP rocks in the Moldanubian Zone (Bohemian Massif). *Journal of Metamorphic Geology*, doi:10.1111/jmg.12121

O’Brien, P. & Vrána, S., 1995. Eclogites with a short-lived granulite facies overprint in the Moldanubian Zone, Czech Republic: petrology, geochemistry and diffusion modeling of garnet zoning. *Geol Rundsh.*, **84**, 473–488.

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The Saxo-Danubian plutonic belt: a late Variscan structure linking West Bohemia and South Bohemia

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Granites are important indicators of thermal and tectonic processes occurring in the lower crust and the upper mantle. By their typology they provide information on the nature of their source rocks, although one must be aware of magma modifications that occur, for example, through later mixing or assimilation. Moreover, granites can be precisely dated by geochronological methods. Granitic plutons are thus, in a way, windows through which the deep infrastructure of orogens and their evolution can be viewed.

Although much discussed, but little understood, the abundance of late- to post-tectonic granites is a distinct feature of the Variscides. Various tectonic scenarios have been invoked to explain this abundance. They include anomalously strong crustal thickening plus radiogenic heating, a late Variscan Andean-type subduction setting, and post-collisional delamination of mantle lithosphere (Gerdes *et al*., 2000, Henk *et al*., 2000). A new aspect highlighted over the past years is that the Variscan granites of the Bohemian Massif cannot be treated as a single genetic entity. They include at least five plutonic belts of slightly but significantly different ages, each having its individual petrogenesis and tectonic environment (Finger *et al*., 2009). One of these is the Saxo-Danubian granite belt (SDGB), a ~400 km long magmatic megastructure that links the Fichtelgebirge/Erzgebirge Batholith of the Saxothuringian Zone with the South Bohemian Batholith in the Moldanubian Zone. Both batholiths contain similar granite types and there is also a remarkable synchronicity of the intrusion ages. The plutonic evolution of the SDGB started towards the end of the Visean with the formation and ascent of large volumes of high-T, lower crustal magmas, that crystallized mostly as coarse-grained K-feldspar-phyric granites. These coarse “early granites” intruded approximately simultaneously over the whole length of the SDGB within a fairy short time span of no more than 8 million years between 328 and 320 Ma. This is a strong argument for the existence of a powerful and rapidly introduced heat anomaly below this region. A rapid temperature increase in the source level can also be inferred from the observation that magmas of different melting behaviour (I- and S-type granites, diorites) intruded contemporaneously. Since other parts of the Bohemian Massif were magmatically quiet at that time, it would appear that this strong late Visean/early Namurian heat anomaly had developed only below the south-western sector of the massif. Granites of a second generation (310 to 317 Ma) are less voluminous and occur preferentially along the southwestern periphery of the SDGB. Younger, ~300 Ma old intrusions have also been encountered in the SDGB but are comparably rare.

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Phases of extensional deformation and rotations within a few million years interval: an integrated paleomagnetic and structural study (Pohorje, Slovenia)

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We reconstructed the deformation history of the Pohorje pluton, related subvolcanic rocks and surrounding sediments in NE Slovenia. Methods involved classical field structural measurements, microtectonic observations in thin sections and different approaches of paleomagnetism. Particularly, we compared the main directions of deformation and the main axis of the anisotropy of magnetic susceptibility (AMS). We extended and reinterpreted our existing data base of Márton *et al*. (2006).

The granodioritic-tonalitic Pohorje pluton suffered ductile deformation in the greenschist-facies, which is recorded by both AMS and microfabric characteristics. The deformation shows varying style within the pluton; extensional in the south and strike-slip type in the northern parts, respectively. Sub-horizontal (S) and steep foliation (N) is well developed, while associated with ENE–WSW (S) and SSE–NNW (N) lineation are recorded by stretched minerals and K_1 AMS axis. This deformation occurred just after intrusion at 18.6 Ma (Fodor *et al*., 2008), during the imminent cooling of the plutonic rocks (18.6–18.4 Ma).

After this phase, at ca. 18.4–17.5 Ma, the pluton was intruded by andesite, dacite and aplite dykes. The AMS indicate ca. E–W minor extension, which is sub-perpendicular to the dykes themselves. During and after this event, the pluton underwent ca. 70°–80° clockwise rotation. After this rotation, at the end of Early Miocene (17.5–16 Ma) the just deposited cover sediments suffered incipient ductile extensional deformation, still at horizontal position. The NE–SW or E–W extension was recorded by AMS, and also by pre-tilt normal faults which are associated with mesoscopically ductile fault-related folding. This was followed by 25–45° CCW rotation.

Fodor, L. I., Gerdes, A., Dunkl, I., Koroknai, B., Pécskay, Z., Trajanova, M., Horváth, P., Vrabec, M., Jelen, B., Balogh, K. & Frisch, W., 2008: Miocene emplacement and rapid cooling of the Pohorje pluton at the Alpine-Pannonian-Dinaric junction: a geochronological and structural study. *Swiss Journal of Earth Sciences* **101** Supplement 1, 255–271.

Márton E., Trajanova M., Zupancic N. & Jelen B., 2006: Formation, uplift and tectonic integration of a Periadriatic intrusive complex (Pohorje, Slovenia) as reflected in magnetic parameters and paleomagnetic directions. *Geophys. J. Int.* **167**, 1148–1159.

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Research on thermally loaded rock – perspectives of underground thermal energy storages

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Efficient and inexpensive energy storage systems undoubtedly play a significant role in the modern sustainable energy strategy. The thermal energy storage, defined as the temporary storage of thermal energy at high or low temperatures, appears to be the most appropriate method for correcting the mismatch occurring sometimes between the energy supply and demand. In the Underground Research Centre Josef in Czech Republic, granitic rock was studied as a host environment of the underground thermal energy storage. In-situ experiment has been set up to evaluate influence of cyclic heating up to 95°C and cooling on the thermo-hydro-mechanical and chemical characteristics of the rock. Long-term in-situ heating experiment was designed to describe changes in geomechanical, chemical, petrological and hydrogeological properties of granitoids during and after repeated heating and cooling cycles. Duration of one full cycle of heating – cooling lasted from several days up to nine months.

Specific objectives were determined and verified:

- the extent and range of possible influence of thermal stress on the structure of granitic rocks,
- the possibility of changes in hydraulic, hydrochemical, petrographic and geotechnical parameters of rocks in relation to the distance from the heat source,
- evaluation of effective rock thermal parameters and correlation with numerical models involving temperature, stress, strain and hydrodynamic simulations.

Monitoring boreholes are used for application of non-destructive measuring methods, particularly for the monitoring of hydraulic (water pressure and permeability), geotechnical (stress and strain meters), thermodynamic (temperature) and microseismic data. Results indicate very rapid increase / relaxation of stress and strain in the rock induced by fluctuations in heating intensity. The induced strain is almost completely reversible, only near the free surface of the rock irreversible changes may occur. Thermal load of the rock mass has also a measurable effect on hydraulic permeability of the rock environment. Moreover, present results suggest also important impact of rock heating to intensive growth of specific microorganisms, which may significantly influence future underground industrial applications. The petrological and petrographical parameters were studied in laboratory conditions using samples from the experimental locality.

Cyclic thermal loading has significant and measurable effect on mechanical behaviour of the host rock. Experiment results will also be fully utilized in the future in a topic different from the present research, i.e. in the issue solving the repositories of spent nuclear fuel in deep geological structures.

Structural evolution of Carpathian thrust front east of Tarnów (SE Poland)

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Based on structural interpretation of 2D and 3D seismics, completed with borehole geophysics and geological data from the surface, serial geological cross sections of the Carpathian orogenic front near to the town of Pilzno were set up and geometrically and kinematically verified, using restoration techniques of Midland Valley's software MOVE™. This made it possible to construct a model of tectonic evolution for the studied segment of the orogenic front.

In the end of the early Miocene, the Outer Carpathian thrust front had approached a position at a distance of not less than 5 to 7 km south of its present location and it was probably characterized by a topography of a flysch wedge that tapered off to the north. The Skole nappe Upper Cretaceous to Oligocene flysch of the wedge was partly onlapped from the north by Miocene (Badenian) sediments of the Carpathian foredeep basin. Following the foredeep deposition of the evaporite series of Wieliczka (chloride facies) and Krzyżanowice (sulphide facies) formations and of the lower part of the supra-evaporitic detrital Machów formation, the final stage of the Carpathian wedge northerly thrusting took place. The sole thrust of the Skole flysch wedge propagated northward into the Miocene of the foredeep along the chloride-facies evaporite horizon to a distance of up to 5 km from the flysch wedge tip. In this way, a new structural unit, made of thrusted foredeep sediments, the Zgłobice thrust unit, became accreted to the Carpathian orogenic wedge in its fontal part. Fault-propagation anticlines (frontal anticlines) were formed first in the Badenian strata above the northern limit of the newly propagated segment of the sole thrust, which coincided with the northern extent of the evaporite chloride facies. These anticlines were subsequently buried by abundant synorogenic late Badenian sediments and the deformation in the Miocene strata moved rearward, to the zone located directly above the flysch wedge tip. The wedge, while translating northward on top of the chloride facies rocks, split the Badenian foredeep succession into two packages, which brought about the formation of a major backthrust, that must have propagated upward to the surface. The ongoing deformation was accommodated also by a minor triangle zone developed within the evaporites above the flysch wedge tip and by large-scale folding of the Zgłobice unit Miocene in the backthrust's hangingwall. The folding produced an up to 3 km-wide frontal monocline in the Miocene strata. The monocline resulted from underthrusting and uplifting of the Badenian upper package (the Zgłobice unit) by the horizontally northward-to-northeastward moving Skole nappe flysch wedge. The Zgłobice unit thus represented a passive roof to the major backthrust. In the backthrust's footwall preserved were Badenian deposits resting transgressively on the flysch and not included in the Zgłobice unit, essentially undeformed, though locally upturned at the tectonic contact.

The Carpathian frontal thrust in its northernmost segment, underlying the Zgłobice unit foredeep strata, either died out to the north under upper Badenian overburden sediments as a blind thrust, or, locally, propagated to the surface as an emergent thrust. Which of these situations occurred, depended mostly on the (highly variable) topography of the foredeep basin floor, composed of Mesozoic rocks.

Which structural style to choose for constructing 3D geological model of the Lublin basin? Constraints from 2D seismic

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Preliminary results of 2D seismic interpretation, constituting the basis for setting up a 3D structural model for the Lublin basin are presented. The Lublin basin has been an object of borehole- and seismic-based comprehensive geological studies for many years. The concepts about its structural style have been, however, widely varied throughout the years and there is still lack of consensus in this respect among researchers.

One of the first regional tectonic models of the area was by Żelichowski (1972), who postulated that the Lublin basin represented a tectonic graben and the tectonic style of the area was that of differentially subsided fault blocks. Pelc (1999) suggested a significant role of shale diapirism in producing the main regional structures (e.g. the Kock fault zone). A new tectonic model of the Lublin basin was proposed by Antonowicz *et al*. (2003). These authors interpreted the basin in terms of thin-skinned tectonics as a passive-roof syncline on top of a regional-size décollement. This concept was subsequently criticized by Dadlez (2003) and Narkiewicz (2003). Krzywiec & Narkiewicz (2003) proposed a transpressional origin for the structures in the Lublin basin and ascribed their formation to the Variscan orogeny.

Results of our interpretations show the Devonian and Carboniferous strata to be cut by mostly NW–SE trending fault zones, composed of thrusts and backthrusts, often with steep attitude, locally defining classical triangle zones. Major thrust faults are accompanied by fault-propagation folds (locally of pop–up characteristics) and are rooted in a detachment in Silurian shale rocks. In the basin's basement identified were high-angle major faults of NW–SE trend, in general throwing to the SW. The Kock fault zone is interpreted here as a major thrust fault detached in the Silurian shales, that propagated into Carboniferous coal-bearing strata, and that is located above a major normal fault in the basement. The SW margin of the Lublin basin represents a limb of a passive syncline which developed above a backthrust dipping to the NE. In its upper part the backthrust is locally cut by SW-dipping thrusts.

Thereby, in our opinion, the structure of the Lublin basin does not have a characteristic of a simple tectonic graben. Instead, in the light of our analysis, it shows features of fold-and-thrust tectonics, albeit with moderate intensity of deformation, developed in a thin-skinned scenario. This interpretation confirms that the basin inversion occurred during the Variscan orogeny and is close to the ideas expressed earlier by Antonowicz *et al*. (2003). The seismic data interpreted in the frame of this research do not allow a critical assessment to be made of the idea of a strike-slip component of the motion on the NW–SE faults. Such a component is, however, likely and deserves further studies.

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Palaeogeothermal gradient reconstruction for the Carboniferous units in Upper Silesian Coal Basin, Czech Republic

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The deep boreholes in the Upper Silesian Basin provide valuable material for the study of coalification in relation to burial depth and temperature. One-dimensional (1-D) modelling of the burial history and thermal maturity was performed at 19 well locations using PetroMod software. The model includes stratigraphic units from the base of the crystalline Brunovistullian, through the Devonian up to the Namurian A, B and C to the Miocene and Carpathians nappes at the surface. The Carpathian nappes were not the subject of interest and were therefore combined as one unit in the model and were not tested.

The 295 Rock Eval pyrolysis measurements were available. The maximum pyrolytic temperature (T_{max}) varies from 423 to 525°C. The correlation of the T_{max} and random vitrinite reflectance (R_r) demonstrated the linear increase of both parameters within the observed rank. Thus the T_{max} could be used as a maturation parameter. A comparison of the curve inclination for vitrinite reflectance and maximum pyrolytic temperature indicated that the regional paleo-heat flow pattern was uniform during the period from the Visean to the Westhpalian. The observed regional differences in maturation patterns are linked to the tectonic features described in the area.

Based on the results of the 1D model, the regional rank distribution can be correlated with an increased thickness in the missing units, rather than with changes in the geothermal gradients.

The expected thickness of the missing Westphalian sediments varies from 1,800 to 3,000 m. The heat flow scenario used in 1D models starting from 80 mW/m^2 during the Paleozoic decreases to 52 mW/m^2 with another increase up to 72 mW/m^2 during the Jurassic. After the Jurassic a continuous decrease in the heat flow is assumed. The following thermal and subsidence evolution did not change the thermal maturity pattern received during Carboniferous burial.

Moho depth model from GOCE gravity gradient data for the Central Asian Orogenic Belt

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The Central Asian Orogenic Belt (CAOB) represents one of the largest accretionary orogens on Earth covering almost one third of the total surface of the Asian continent. The crust of this accretionary system grew during the Palaeozoic at the periphery of the Siberian cratonic nucleus by the successive amalgamation of different types of crust (cratonic, oceanic, passive margin, magmatic arc, back-arc, ophiolites, accretionary wedge) followed by a Mesozoic collisional phase. Since the Cenozoic, it has been evolving as an intracontinental orogen. The geophysical investigations remain scarce due to the remoteness of the area. A systematic analysis of the crustal thickness has been omitted yet, although the geometry of the crust-mantle boundary (Moho boundary) provides key information on the evolution of the lithosphere. Therefore, determining the Moho geometry and the isostatic state of the CAOB is crucial for the understanding of its tectonic history. The Gravity field and steady-state Ocean Circulation Explorer (GOCE) is the European Space Agency's (ESA) satellite gravity mission to determine the Earth's mean gravity field. Among other things, GOCE delivers gravitational gradients data which are the first satellite data of this nature. These data can improve the modelling of the Earth's lithosphere in two major aspects: (1). Update the Moho depth model; (2). Analyse the gravity anomalies located at the upper mantle and lower crustal levels.

In this study, the gravity gradient data set of GOCE are used to determine the topography of the Moho for Mongolia and its surroundings, using inversion of gravity data and calculation of the isostatic Moho from topographic data with the software LithoFLEX. In addition, we implemented the same process to the WGM2012 grid of the Earth's gravity anomalies and these results are compared together with those obtained for the GOCE gravity data. The results of the gravity inversion are constrained by the few xenolith studies and the rare seismic data available: the receiver function seismic method for north and central Mongolia, deep seismic sounding and seismic reflection profile in northern China. Then, the effects of isostatic compensation are evaluated by the comparison between the results of the gravity inversion and the isostatic Moho. Finally, a 3D modelling of the gravity gradients is performed over the key parts of the Central Asian Orogenic Belt. These results will allow in a near future updating and improving the geodynamic evolution of this accretionary orogen.

Nature of the lower crust of the Mongolian Central Asian Orogenic Belt inferred from gravity and geochemical data

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The Central Asian Orogenic Belt (CAOB) in Mongolia consists of Proterozoic domains surrounding late Proterozoic to early Paleozoic accretionary wedges and Siluro-Devonian oceanic domain. Previous study reveals that the tectonic domain boundaries are traceable through upper crust only as the upper crust with oceanic affinity is underlain by a layer of homogeneous gravity signal. Forward gravity modelling suggests that this layer is not formed of a high-density material typical of lower oceanic crust, but is composed of low to moderate density rocks typical for continents. The nature of this lower crust is constrained by whole-rock geochemistry and zircon Hf isotopic signature of abundant late Carboniferous high-K calc-alkaline and early Permian A-type granitoids intruding the early Paleozoic accretionary wedge and Siluro-Devonian oceanic domain. A possible genesis of these granitoids is seen in an anatexis of juvenile, metaigneous (tonalitic–gabbroic) rocks of Late Cambrian age. The presumed source can be correlated with recently discovered remnants of the “Khantaishir” arc (520–495 Ma) further north. In order to test this hypothesis, the likely modal composition and density of Khantaishir arc-like protoliths are modelled at granulite- and higher amphibolite-facies conditions. It is shown that the current average density of the lower crust inferred by gravity modelling (2730±20 kg/m^3) matches best leucotonalite to diorite metamorphosed at granulite- and/or amphibolite-facies conditions. Based on these results, a new concept of the Mongolian CAOB accretionary architecture is proposed whereby the mafic accretionary wedge and oceanic upper crust is underlain by allochthonous, Cambrian arc-derived lower crust. Possible tectonic models, explaining relamination of allochthonous felsic to intermediate lower crust beneath mafic and dominantly oceanic upper crust are proposed and discussed.

Garnet–clinopyroxene-bearing ultrahigh-pressure rocks from Eger Crystalline Complex: their P–T evolution

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Presence of diamond enclosed in garnet and zircon in garnet-clinopyroxene bearing rocks from the Eger Crystalline Complex documents that they experienced ultrahigh-pressure conditions (Kotková *et al.*, 2011). Despite strong overprint under granulite-facies conditions, earlier stages of the evolution can be reconstructed based on careful petrographic investigation and using thermobarometric methods and thermodynamic modelling.

Ultrahigh-pressure metamorphic conditions have been constrained using Ti-in-zircon thermometry, which yields values of up to 1300°C at 5 GPa, where it intersects graphite-diamond transition curve. Homogenized garnet cores with X_{Grs} up to 0.32 and X_{Mg} up to 0.40 contain up to 0.21 wt. % TiO_2 corresponding to temperatures of 930–970°C at 4 GPa. These temperatures can be underestimated due to the observed exsolution of rutile needles in garnet cores and possible diffusion of Ti towards the garnet rim. Omphacite inclusion in garnet contains 34 mol. % of jadeite component and 11 mol.% of Ca-Tschermak component. This composition corresponds to 2.42 GPa at 1050°C using JAQ thermobarometry. Application of GASP equilibrium and ternary feldspar solvus thermometry for the assemblage garnet (rim) – ternary feldspar (matrix) – kyanite – quartz yields 1.98 GPa at 1050°C. The linear combination of GADS and GAHS equilibria for the assemblage garnet (rim) – clinopyroxene – plagioclase – quartz defines Mg and Fe exchange-based thermometer with the intersection of the three equilibria at 880°C and 1.4 GPa.

Thermodynamic modelling using Perple_X software including compositional isopleths of X_{Jd} in omphacite and X_{Grs} in garnet shows P–T conditions comparable to those presented above for the measured mineral compositions. In addition, it reveals metastability of kyanite at pressures bellow ca. 2.5 GPa. Kyanite, and omphacite, are consumed upon transition from eclogite- to granulite- facies conditions, producing garnet and plagioclase. This newly grown garnet is enriched in Mg, and suggests that the commonly observed X_{Mg} increase in garnet does not have to be related to prograde evolution.

These results document near-to-isothermal decompression from UHP/UHT conditions, followed by cooling from high-pressure granulite-facies conditions. Such an evolution is consistent with rapid exhumation documented by geochronological data.

Kotková, J., O'Brien, P. J. & Ziemann, M. A., 2011. Diamond and coesite discovered in Saxony- type granulite: Solution to the Variscan garnet peridotite enigma. *Geology*, **39**, 667–670.

Growth of accretionary wedges and pulsed ophiolitic mélange formation by successive subduction of volcanic elevations

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Fault-bounded coherent belts alternating with belts of mélanges are common in accretionary wedges and are usually interpreted as a result of imbrication along subduction zone megathrusts. Using the Neoproterozoic/early Cambrian Blovice accretionary complex (BAC), Bohemian Massif, as a case example, we present a new model for the origin of alternating belts through the repetition of several cycles of (1) offscraping and deformation of trench-fill sediments to form the coherent units, interrupted by (2) arrival and subduction of linear, trench-parallel volcanic elevations. After initial accretion of the trench-fill sediments, resulting in the formation of a coherent belt, subduction of a volcanic ridge composed of massive and pillow basalts is followed by its tectonic disruption and incorporation into host sedimentary olistostromes to produce polygenetic ophiolitic mélanges. The olistostromes were formed in the trench as a result of extensive mass-wasting processes from the uplifted wedge, thickened by the subducted ridge. Formation of multiple, repeated ophiolitic mélange belts within a single wedge, separated by belts of coherent trench-fill siliciclastic rocks, may be explained in terms of subduction of an oceanic plate carrying an array of linear, trench-parallel asperities. We argue that the geochemistry, geometry and size distribution of basalt inclusions, the tectonic basalt/slate contacts and the lack of basalt clasts within the olistostromal sedimentary matrix in the mélange belts of the BAC are compatible with subduction and tectonic disruption of a back-arc basin with horst-and-graben topography rather than with an olistostromal origin. The six belts in the BAC thus record a combination of frontal or slightly oblique trench sediment accretion interrupted by pulses of mélange formation, the latter caused by the successive arrival of three linear ridges into the subduction zone and emplacement of their fragments into the belts. In this model, the belts progressively young oceanward. In addition, the composition of the trench-fill greywackes, with negligible amounts of small basaltic clasts, suggests that the volcanic ridges were not fragmented in the trench, but at greater depths in the wedge. In general, the whole process may operate repeatedly as long as linear ridges are available and move towards the trench.

Orthogneisses of the Devonian protolith age along the eastern wedge of the Tseel Metamorphic Complex, the Mongolian Altai

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Tseel Metamorphic Complex (TMC) as an important part of a narrow discontinuous belt of metamorphic rocks rimming the southern slopes of the Mongolian Altai is located approximately between Bugat soum in the W and Sag-say river in the E. TMC is dominantly composed of micaschists and gneiss with intercalations of amphibolites, gabbro boudins and deformed granites. Two orthogneiss belts are exposed along the eastern wedge of the TMC.

The southern belt between the TMC in the N and the Devonian–Carboniferous volcano-sedimentary complexes of the Trans-Altai Zone in the S is composed of homogeneous, coarse-grained augen orthogneiss. Mylonitic foliation (steeply dipping to the NNE) is developed along the northern boundary. Southern contact is marked by W–E striking fault. Orthogneiss of the southern belt are of granite to granodiorite composition (67.6–70.2 wt. % SiO_2), high-K calc-alkaline, slightly peraluminous. The chondrite normalized REE patterns show only insignificant Eu anomalies, with fractionated LREE and flat HREE.

The northern belt is NW–SE oriented and formed by medium-grained, texturally variable orthogneisses with layers of amphibolite and two-mica gneisses. Contact with the TMC is obscure, probably tectonic; the volume of amphibolite and gneiss layers increases towards the NE into the metamorphosed part of the Tugrug Fm. Orthogneisses from the northern belt are calc-alkaline with composition from granite to tonalite (SiO_2 = 68.6–76.9 wt. %) and strongly variable chondrite-normalized REE patterns.

Zircons from the coarse-grained orthogneiss samples K132 and Y068 of the southern belt both show well-developed magmatic oscillatory zoning and yield U-Pb ages of 375±4 and 372±2 Ma, respectively, suggesting Middle Devonian emplacement. Zircons from one orthogneiss sample Y229 of the northern belt exhibit igneous characteristics and gave $^{206}Pb/^{238}U$ ages ranging between 360 and 401 Ma, with a weighted mean of 374±11 Ma, representing the emplacement age.

Our data confirm Devonian magmatism at the active continental margin in this part of the Mongolian Altai. While the orthogneisses of the southern belt were sheared along the boundary between the Tseel and Trans-Altai zones, those of the northern belt were deformed in a zone transitional between the Tseel metamorphic and Tugrug volcanosedimentary complexes.

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Cretaceous deformations of the Keszthely Hills and the northern part of the Zala Basin

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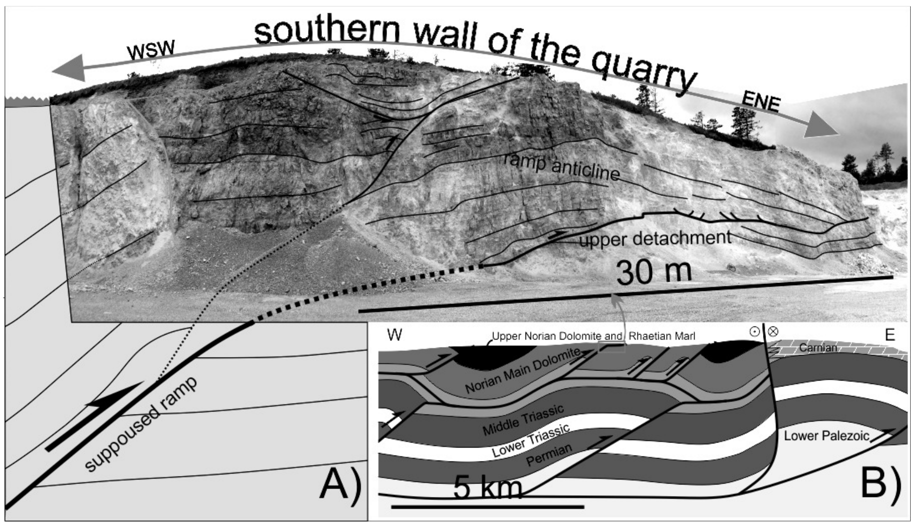
The goal of the present work is to investigate the folding of the study area, which is situated in the southwestern part of the Transdanubian Range. The Keszthely Hills are made up Upper-Triassic and Neogene rocks. In its subsurface continuation, in the northern Zala Basin, the Triassic-Jurassic is covered by late Cretaceous (Gosau) and Miocene sediments. We used fault-slip data, and 3D seismic data, to investigate the pre-Cenozoic structures.

The N–S strike of the main compressional structures of the study area differs from the NE–SW striking synclinal axis of the Transdanubian Range. Thus previous works could not define precisely the number and ages of the compressional events.

We could determine an uncertain NNW–SSE compressional, and a well-detected E–W compressional event, with a post-Early Cretaceous, pre-Senonian age. Mesotectonic data suggest a younger NE–SW compressional stress field. We managed to identify map-scale structures (ramp-anticlines related to flat-ramp-flat detachment surfaces) in the dolomite quarries of the Keszthely Hills (Figure A).

The distribution of Triassic formations suggests two major synclines in the Keszthely Hills (Budai *et al*., 1999). The wavelength of these folds is about 10 km, in contrast with the detected ramp anticlines, whose wavelength is only a few hundred meters. The presence of the two wavelengths of folds can be connected by two main detachment surfaces (Figure B). The Carnian Marl is probably the floor detachment of the smaller-scale folds, while this horizon may represent the roof-detachment for the large-scale folds. Below this detachment, duplex system can be postulated which is floored by the deepest detachment at the Lower Paleozoic level (Figure B). All these structures are in agreement with the model of Tari (1994), and supports that the Transdanubian Range is a thrust and fold belt.

Budai, T., Csillag, G., Dudko, A., Koloszár, L. (1999): A Balaton-felvidék földtani térképe, 1:50.000. Magyar Állami Földtani Intézet.
Tari, G. (1994): Alpine Tectonics of the Pannonian basin. PhD. Thesis, Rice University, Texas, USA. 501 pp.



A) Ramp anti-cline and upper detach-ment in the Pilikán quarry, Keszthely Hills;
B) Simplified cross section of the Keszthely Hills.

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Alpine metamorphic and magnetic fabric overprints of the Variscan basement in the Gemeric Unit of the Western Carpathians

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The rocks investigated in the Gemeric Unit of the Western Carpathians comprise the Early Palaeozoic metasediments and metavolcanics, Permian to Early Triassic granites, and Late Palaeozoic molasse (meta)sediments. In addition to Variscan greenschist facies metamorphism in the Early Palaeozoic basement, all the rocks underwent Cretaceous (Alpine) low-grade metamorphism which significantly modified their mineral composition and rock fabric. During this process, the original magnetic minerals were destroyed partially up to entirely and new, mostly paramagnetic, minerals were created. This is indicated by the mean susceptibility, which is in general low, in the order of 10^{-4}.

In the Early Palaeozoic metasediments, the magnetic fabric is entirely metamorphic/ deformational in origin. In the Early Palaeozoic metavolcanics, the magnetic foliations are partly parallel to the Variscan metamorphic foliations and partly to the disjunctive foliations. Their magnetic fabrics probably represent gradual transition from Variscan to Alpine fabrics. The preservation of Variscan fabrics is documented also in some sedimentary rocks that were overprinted by contact metamorphism around granite intrusions of Permian-Triassic age. In granites, the magnetic foliations are near the Alpine mesoscopic disjunctive foliation. The magnetic fabric, originally magmatic in origin, was finally reshaped by strain just before disjunction, while the rock was still semi-ductile due to Alpine metamorphism. In the Late Palaeozoic (molasse) metasediments, the magnetic foliations are near the Alpine metamorphic foliations that are mostly parallel to the original bedding. The magnetic fabrics in all the rock types investigated indicate the Alpine overprints whose intensity may have been variable, ranging from relatively weak to obliteration.

The pyrrhotite fabric relationship between the slates of the Jílové Belt and the neighbouring granitoids of the Central Bohemian Plutonic Complex as revealed in the Josef Gallery

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The structural relationship between slates of the Jílové Belt and neighbouring granitoids of the Central Bohemian Plutonic Complex was investigated by means of the Anisotropy of Magnetic Suceptibility (AMS) in the Josef Gallery at Mokrsko, where a contact between these two units is well exposed. The AMS is dominantly carried by pyrrhotite in the slates and in a part of granitoids, while in the other part of granitoids it is carried by paramagnetic mafic silicates and magnetite. In both the rock types investigated the pyrrhotite shows a conspicuous preferred orientation by crystal lattice. In the rocks of the Jílové Belt, the magnetic foliations defined by the pyrrhotite basal planes are very steep being more or less parallel to a NNE–SSW mesoscopic cleavage. In addition, they experience a very faint fan, whose axis is sub-horizontal and oriented N–S. In the granitoids (granodiorite to tonalite), in which the dominant AMS carrier is pyrrhotite, the magnetic foliations are also very steep, but more or less perpendicular to the cleavage and magnetic foliations in slates of the Jílové Belt. Their orientations correspond to those of ubiquitous E–W subvertical quartz micro-dykes in tonalite that are parallel to ore veins. Also in these rocks, the pyrrhotite basal planes create a very faint fan, but its axis is more or less vertical. In the granitoids, whose AMS is dominantly carried by paramagnetic mafic silicates and/or magnetite, the magnetic foliations are very steep, azimuthally compatible with the cleavage in the Jílové Belt. Even though pyrrhotite is evidently secondary in the granitoids of the Central Bohemian Plutonic Complex, it displays a conspicuous preferred orientation by crystal lattice. This find opens numerous questions concerning the pyrrhotite mineralization in the region investigated and its time relationship to deformation phases identified by field structural research.

Identification of the Variscan ophiolite suture in the Western Carpathians: implications for the geological structure and geodynamic evolution of this area

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Ophiolite sutures belong to the most important structural elements of orogenic belts. They represent not only the final stage of the ocean closure during the orogeny but also a fossil boundary between colliding lithospheric plates. Ophiolite nappes representing more or less complete profiles through the former oceanic basin crust and ophiolite mélanges containing blocks of the oceanic crust are main components of the ophiolite sutures.

In the Western Carpathians, where only relics of the Triassic-Jurassic Meliata Ocean crust had been known, also the Variscan oceanic crust relics have been found during the several last years. They are represented by the metamorphosed dismembered incomplete ophiolite sequence, which is a component of three lithostratigraphic units: (1) Pernek, (2) Zlatník and (3) Ochtiná Groups. The Pernek Group is located in the NW margin of the Tatric Superunit (area called as the Infratric Unit). It forms an imbricated tectonically reduced ophiolite nappe composed of the medium-grade metamorphosed basalts, dolerites and gabbros with small amount of deep-sea sediments in its uppermost part. The Pernek Gr. is the Upper Devonian (371±4 Ma) in age and it was penetrated and metamorphosed by granitoid intrusions during the Lower Carboniferous (ca. 350 Ma). The Zlatník and Ochtiná Grs. build up the northern margin of the Gemeric Superunit. The Zlatník Group is divided into two formations: (1) the Grajnár Fm. (nappe) composed mostly of low metamorphosed basalts probably Upper Devonian (ca. 380 Ma) in age and (2) the Závistlivec Fm. represented by the low-grade metamorphosed sedimentary mélange with enclaves of basalts, dolerites and gabbros, rarely also with the acid igneous rocks. The Ochtiná Gr. is similar to the Závistlivec Fm., but it comprises also enclaves of ultramafic rocks. Reef carbonates forming its uppermost part were dated as Lower Carboniferous. Majority of metabasalts in all mentioned units have identical geochemical signature transitional between N- and E-MORB types pointing to affinity to the CM (continental margin) ophiolite group. The Pernek Group represents a most distal relict of the oceanic floor formed just in the mid-ocean ridge, whereas mélanges of the Ochtiná Group and Závistlivec Fm. probably originated in the accretionary wedge during active subduction. The Grajnár Fm. seems to be a relic of the uppermost oceanic crust from the marginal area of oceanic basin not too remote from the ensialic magmatic arc. The Pernek, Zlatník and Ochtiná Groups we interpret as parts of the single Variscan ophiolite suture formed by closure of the Upper Devonian/Lower Carboniferous Pernek Ocean and tectonically disintegrated during Alpine orogeny. The original suture was a fossil boundary separated two lithospheric paleoplates with different Variscan tectono-thermal and magmatic history. The southern plate (in present day coordinates) was spared extensive plutonic activities and metamorphic reworking. Record of geodynamic evolution from the Ordovician arc setting to the Devonian rifting and oceanic opening seems to be preserved here. Subduction of the Pernek Ocean beneath the northern plate led to formation of a magmatic arc connected with the intensive metamorphism in the upper crust caused by elevated thermal flow together with granitoid plutonism. Lower Carboniferous (360–350 Ma) I and S-type granitoids in the Veporic and Tatric Superunits of the Western Carpathians could be products of this plutonism.

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The Cambrian Khantaishir Arc – a conspicuous and geotectonically important structure in the Lake Zone of the Mongolian Altai (Central Asian Orogenic Belt)

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The plutonic rocks of the newly defined Khantaishir magmatic arc intruded the Neoproterozoic accretionary wedge of Mongolian Altai (Lake Zone) in Cambrian times (538±3 to 494±3 Ma (2σ), LA ICP-MS Zrn dating). The magmatic complex was later underthrust below the southerly Palaeozoic volcano-sedimentary prism (Gobi-Altai Zone). The arc shows a section from deep, (ultra-) mafic cumulates (hornblendites and Amp gabbros) to shallower levels of the magmatic system dominated by Amp–Bt diorites and tonalites. The P–T conditions obtained by amphibole thermobarometer (Ridolfi *et al*., 2010) show that the gabbros crystallized at ca. 930–975°C and 0.35–0.51 GPa, while the tonalites record only ca. 800–845°C and 0.1–0.2 GPa.

The rocks are intermediate to ultrabasic (SiO_2 = 39.2–61.8 wt. %), metaluminous and mostly subalkaline, except for the ultrabasic types. Sodium always prevails over K (Na_2O/K_2O = 1.3–9.7). The rocks are mostly low-K calc-alkaline. The NMORB-normalized spiderplots show enrichment in hydrous fluid/melt-mobile large-ion lithophile elements (LILE: Rb, Ba, Th, U, K and Pb) over high-field strength elements (HFSE: Nb and Ta) characteristic of igneous arcs. The major-element variations can be modelled by fractionation with, or without, crystal accumulation of ferromagnesian phases (mainly Amp).

The igneous rocks over the whole silica range yielded very low $^{87}Sr/^{86}Sr_{500}$ ratios of 0.7034–0.7044. Such values correspond to magmas derived by (near) closed-system fractionation from depleted-mantle derived melts or from a source with low time-integrated Rb/Sr ratio, such as metabasites. While zircons in two of the diorites give high initial ε_{Hf} values (+8 to +14), the zircons in tonalite are significantly different (ε_{Hf} = +3 to +6). The gabbro contains zircons with both of these components (ε_{Hf} = +4 to +13). This is compatible with the field evidence for the presence of several generations of depleted-mantle derived basic magmas, as well as hybridization between contrasting magma batches including primitive crustal melts.

The lack of significant zircon inheritance, rather primitive whole-geochemistry, low Sr initial ratios and positive, often high ε_{Hf} values imply that the arc was not funded on mature continental crust. Instead, a key role is ascribed to repeated, voluminous depleted-mantle derived melt injections, triggering remelting of a youthful and juvenile metabasic crust. It most likely represented recently accreted oceanic crust.

Ridolfi, F., Renzulli, A. & Puerini, M., 2010. Stability and chemical equilibrium of amphibole in calc-alkaline magmas: an overview, new thermobarometric formulations and application to subduction-related volcanoes. *Contributions to Mineralogy and Petrology,* **160,** 45–66.

The polyphase Variscan tectonometamorphism of the Goszów quartzites, the Orlica-Śnieżnik Dome

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The metavolcano-sedimentary group of the Orlica-Śnieżnik Dome (OSD), NE Bohemian Massif, comprises two, traditionally distinguished informal formations, the Młynowiec Fm. and the Stronie Fm. Both these stratigraphic subunits have disputable protolith ages, so that their mutual stratigraphic relations and tectonic evolution remain uncertain. A thin horizon of the light "Goszów" quartzites occurs between the two above mentioned metavolcano-sedimentary formations, and for years has been considered as the basal unit of the Stronie Fm. They form three different, locally intercalating varieties: Kfs-bearing quartzites, pure quartzites with up to 15% of muscovite and mica-rich quartzites.

We provide the pressure-temperature-time-deformation records of the Goszów light quartzites that improves our understanding of the structure and tectonic evolution of the OSD. Our new Th-U-total Pb monazite geochronological dating performed for eight samples of the light quartzites indicate two age clusters of ca. 364 Ma and 335 Ma, what confirms the presence of diverse, latest Devonian and Visean monazite-forming events in the OSD. However, the monazite study reveals also the previously unrecorded, early Palaeozoic monazite age of ca. 494 Ma, that was obtained for the samples of the K-feldspar bearing variety of the Goszów light quartzites. This additional age corresponds to our previous U-Pb study, showing that ca. 490 Ma zircons form 90% of the zircon population in Kfs-bearing quartzites, and 10% of zircon population in the adjacent mica-bearing, Kfs-absent quartzites. Field and petrographic observations, supported by the geochronological data suggest that the light quartzites originated mainly from quartz sands intercalated by pelitic rocks with occasional admixture of volcanogenic, tuffitic material. The Early Palaeozoic monazite age of ca. 494 Ma is interpreted as the protolith age of the Goszów light quartzites, and related to the volcanic activity. It indicates their temporal affinity with protoliths of the other metavolcano-sedimentary rocks of the Stronie Fm.

The tectonometamorphic record of the Goszów light quartzites, compared to the under- and overlying rock formations, indicates that the whole metavolcano-sedimentary group of the OSD functioned as a single and integral lithotectonic unit, with no visible structural or metamorphic discontinuities. Structural studies and thermodynamic modeling indicates that the development of tight N–S trending folds and axial penetrative metamorphic foliation was related to E–W directed tectonic movement and metamorphic progression from 500ºC to 640ºC at 6–7 kbar at which the assemblage Grt(rim)-Bt-St-Ms-Qz developed. The light quartzites usually contain kyanite and/or staurolite suggesting that the entire quartzitic horizon experienced amphibolite facies conditions. Subsequently, under the retrogressive conditions of below 500ºC, the foliation was reactivated as a result of subsequent N–S directed ductile shearing and extension. The results referred to the Goszów light quartzites thus exemplify that the penetrative structures in the OSD: the metamorphic foliation and N–S trending lineation are composite structures. The monazite metamorphic ages of ca. 364 Ma and 335 Ma can be related to these approximately E–W and N–S oriented tectonic movements, respectively.

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Metamorphic reactions and textural changes in coronitic metagabbros from the Teplá crystalline and Mariánské Lázně complexes, Bohemian Massif

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Coronitic metagabbros occur as small isolated bodies along the contact between the Mariánské Lázně complex (MLC) and the Teplá crystalline complex (TCC) NW of the Bohemian Massif. These bodies are embedded mainly in micaschist of the TCC or amphibolites and eclogites of the MLC. Metagabbros show variable metamorphic and textural characteristics with respect to their magmatic mineral assemblage and degree of metamorphism. The aim of this study is to characterize mineralogical, chemical, and microstructural changes related to coronitization in selected representative samples. In addition, the associated calculation of P–T conditions can help to clarify the evolution of the MLC and TCC boundary as well as to provide constrains on formation of corona microstructures. Magmatic mineral assemblages and microstructures in the metagabbros are generally well preserved. They are characterized by the presence of Plg (labradorite), Cpx (diopside to augite), Opx (enstatite), Amp (edenite to pargasite), Bt, Ilm and Sp, some samples additionally contain primary Ol or Qtz. Metamorphism is mainly reflected by formation of single or multiple coronas at the contact of Plg and other primary magmatic minerals. Following coronas or their sequences in direction towards Plg can be observed: Cpx is surrounded either by no corona, or by narrow layer of Amp with Al increasing at the contact with Plg, which may be followed by Grt layer. Amp can be surrounded by a layer of Opx+Plg symplectite. Opx shows high variability in developed coronas with following sequences observed in different samples: 1) Hbl; 2) alternation of Hbl+Plg and Opx+Plg symplectites 3) Cumm→Act+Qtz symplectite→Hbl→Grt 3) Cpx+Hbl→Opx+Plg symplectite→Grt. Bt is surrounded by Amp and/or by symplectitic corona of Opx+Sp, occasionally followed by Grt. Ilm is surrounded by tiny Zrc grains while Grt corona occurs occasionally. Ol is always enveloped by double corona of Opx followed by Amp occasionally alternating with Opx+Sp symplectite. Following features appear with respect to the primary magmatic mineral assemblage: 1) Grt coronas are developed only in Ol-free samples, 2) Qtz is a part of Act+Qtz symplectites in sample with primary Qtz only. In addition, progressive breakdown of the original magmatic Plg can be described based on the studied sample sequence: 1. crystallization of small (0.X μm) spinel grains and corundum lamellae in the Plg indicating Ca>Al diffusion from Plg accompanied by Mg+Fe diffusion into Plg; 2. breakdown of the magmatic Plg (labradorite) to andesine and anortite; 3. recrystallization of the magmatic plagioclase into fine-grained clusters of zoned Plg grains (increase of Ca to rims) accompanied with Sp, Ky and Crn. P–T conditions were calculated by average P–T calculation mode of THERMOCALC. The conditions calculated for the selected samples from the TCC are 560–615°C and 8–10.5 kbar. P–T conditions from the sample at the eastern margin of the MLC to the west have been estimated to 690°C and 12 kbar. Similar conditions and metamorphic field gradient showing an increase in PT conditions from SE to NW is in a good agreement with previously published data (e.g. Cháb & Žáček,1994).

Cháb, J. & Žáček, V., 1994. Metamoprhism of Teplá Crystalline Complex. KTB Report 94-3, 33–37. Hannover

Multiple prograde metamorphic history of UHP granulites from the Moldanubian Zone (Bohemian Massif) revealed by Y+REEs compositional zoning in garnets

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Preservation of compositional zoning in metamorphic garnet is considered as a powerful tool to reconstruct P–T paths in metamorphic rocks. This is due to the slow diffusion rates of some major but mainly of trace elements, including Y and heavy rare Earth elements (HREEs), which show strong partitioning into garnet. In this investigation, we utilize compositional zoning patterns of major, trace and rare Earth elements in garnet crystals from felsic granulites of the Kutná Hora Complex to reconstruct their prograde metamorphic evolution. The granulites contain lenses and boudins of mantle garnet peridotites and eclogites. Compositional zoning in garnet provides the evidence of pre-granulite facies metamorphic history of the rocks. This is documented by high Y and HREE contents in the core with annuli in the mantle part of garnet grains that are interpreted as the result of two distinct metamorphic events. The core of large garnet with relatively high Ca and bell-shaped manganese contents suggest its formation during a prograde low- to medium- temperature metamorphic event which was coeval with HP–UHP metamorphism. Based on pseudosection modelling by Perple_X thermodynamic software in combination with compositional isopleths of major elements from garnet we are able to reconstruct prograde metamorphic path of felsic granulites. Grs content in combination to Prp and X_{Fe} revealed LT–HP conditions of garnet nucleation. After that, grossular is slightly decreasing and X_{Fe} rapidly decreasing, which leads to increase of pressure and temperature to coesite and even diamond stability field. UHP conditions of these rocks were confirmed by findings of inclusions of coesite and micro-diamond in garnet and zircon. Decompression and cooling during exhumation of the rocks led to partial resorption of garnet and release of trace and REEs into the matrix. The new garnet with high Y+HREEs in the annuli was formed during the granulite facies event at crustal levels. The annuli usually show higher Y+HREE contents compared to core of the prograde HP garnet.

Petrogenesis of the Paleozoic synorogenic granitoids in the southern Altai Orogenic Belt, central Asia: new insights into the crustal evolution of accretionary orogenic system

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The accretionary orogenic belts are characterized by the amalgamation of various terranes of diverse natures to form a huge subduction-accretion complex and are responsible for the sites of major growth of continental lithosphere in our planet. Subsequent anatectic reworking of the accretionary wedge to form granite-dominated continental crust is considered as a principal process responsible for cratonization of accretionary orogens. However, melting of accretionary wedge sediments can be questioned due to cold supra-subduction environment, and therefore granitic magma emplaced in the accretionary wedge was classically interpreted to originate from the mantle due to ridge-trench interaction or slab retreat.

The Central Asian Orogenic Belt (CAOB) is considered as the Earth largest area of Phanerozoic crustal growth. Based on generally depleted Sm-Nd isotopic characteristics of the Paleozoic granitoids, it is suggested that >50% juvenile materials from the mantle contributed to its crust. In the Chinese Altai, voluminous Silurian-Devonian granitoids intruding a greywacke-dominated Ordovician flysch sequence - a giant accretionary complex, were traditionally interpreted as arc magmatic rocks with juvenile/mantle contributions of 50–90%. However, these intrusions exhibit geochemical signatures comparable to the flysch rocks, suggesting that they may have derived from the flysch sequence. Pseudosection modelling shows that the fertile flysch may produce large volumes of granitic-granodioritic melts at granulite-facies conditions, leaving a high density residue such as garnet- and/or garnet-pyroxene-rich granulite in the deep crust. Isostatic residual Bouguer anomaly map and gravity modeling document that a major gravity high over the Chinese Altai coincides with the regional extent of Silurian-Devonian granitoids, implying the likely presence of a high density lower crust comparable to the modelled granulitic residue. Combined with regional available data, this study propose that the Silurian-Devonian granitoids in the Chinese Altai may have originated from partial melting of a pre-existing flysch sequence rather than from an extremely high input of juvenile component from the mantle as proposed previously. The finding of this work may serve as an example where the arc-like magmatic rocks may not necessarily originate through net crustal growth at convergent margins but rather result of crustal recycling. This also imply that accretionary prisms are not necessarily stabilized by arc-type mantle-derived magmas but solely by elevation of heat flow, as proposed for Cordilleran-type convergent margins, and this would lead to the crustal differentiation and growth of mature continental crust in the accretionary wedge.

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Subsidence and thermal history of the Uhřice 18 borehole

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The aim of this study was to make a subsidence and thermal history model of the Uhřice 18 borehole, which is situated in area of the Damborice highlands in the Outer Western Carpathians. The model was created base on the regional geological concept presented in Picha *et al.* (2006) using PetroMod 1D software (Schlumberger). The maximum pyrolytic temperature T_{max} from pyrolysis Rock-Eval and trend for vitrinite reflectance within Mikulov Marls and Myslejovice Fm. were used as calibration parameters. The reliability of resulting model was verified by comparing measured values with model ones.

The final model represents crystalinic basement known as brunovistulicum (Dudek, 1980). Above brunovistulicum are deposits of Paleozoicum represented by carbonates of Macocha Fm. and shales of Myslejovice Fm. Sequence continues with thick Jurassic Mikulov Marls and relicts of Cretaceous sandstones. Following Paleogene strata are formed mostly by claystone and sandstone. On the top of this sequence is the Ždánice nappe that was thrust on the autochtonous basement from 16.5 to 8 Ma (Pícha *et al*., 2006). The main part of the nappe is built with Ždánice–Hustopeče Formation that is assigned to the late Oligocene to early Miocene.

A significantly lower coal rank and different thermal gradient with depth in the Jurassic Mikulov Marls suggests erosion of 1.5–2.1 km from Upper Paleozoic sequence. The Paleozoic heat flow is expected to be 20 mW/m^2 higher than that during the Tertiary.

Dudek, A., 1980. The crystalline basement block of the Outer Carpathians in Moravia: Bruno-Vistulicum. *Rozpravy Československé akademie věd. Řada Matematických a přírodních věd*, **90**, 8, 3–85. Praha.

Picha, F., Stráník, Z. & Krejčí, O., 2006. Geology and Hydrocarbon Resources of the Outer Western Carpathians and Their Foreland, Czech Republic. In: Golonka, J. & Picha, F. (eds) 2006. The Carpathians and Their Foreland: Geology and Hydrocarbon Resources – AAPG Memoir #84. The American Association of Petroleum Geologists, 49–175. Tulsa, Oklahoma, USA.

Three phases activity of the Clay Fault (Barrandian)

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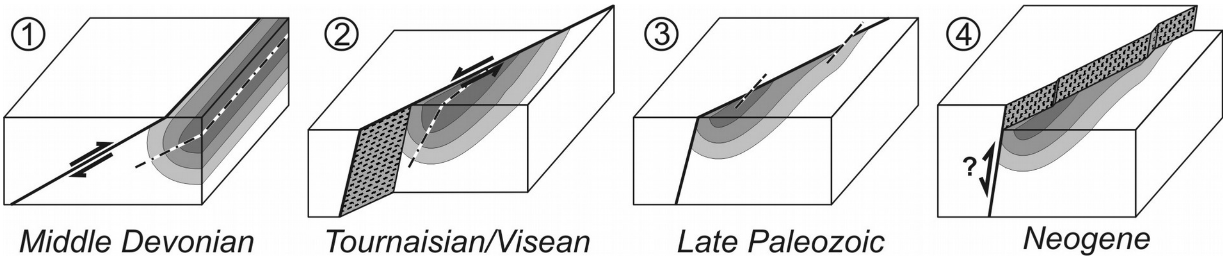
The Clay Fault was recognized in mines of the Příbram and Bohutín ore district and named by ancient miners. The dip varies from 70° to NW to nearly vertical. Havlíček classified this structure as an overturned synsedimentary normal fault. He deduced the Cambrian age of the fault base on his geological map, where lower Paleozoic basalt dike cross-cuts the fault surface. Deformation zone near Clay Fault is by observation of Březové Hory mines powerful up to 60 m. It is possible to distinguish three distinct phases of fault activity. There is mylonite zone with distinct (two) types of mylonites of different ages – the older mylonite with slickenside in the dip direction and the younger mylonite with subhorizontal slickenside. Last fault activity is documented by the youngest tectonic clay (several centimeters powerful in core Clay Fault) that gave the name to the structure. This tectonic clay crosses also variscan Bohutín tonalite, unlike older mylonites. This indicates that the last movement at this break must occur after its intrusion. The fact, that the clay is still in slippery, incoherent form proofs its very young, Neogene age probably. It seems from the course of Clay Fault that it is cross-cutting by younger oblique faults corresponding roughly to the direction of NS because the shift is indicated also by the shift in the other structures (lithological body, discordance surface). This geometry of deformations shows that the last movement on Clay Fault was along the dip direction of the fault plane. The last phase belongs to the “dip-slip” faults group, but it is not possible to clearly determine its sense of movement. The older mylonites (mostly external) of Clay Fault have distinct striations on foliation surfaces oriented along the dip direction. There are microscopically observed deformations with S-C structures and asymmetric pressure shadows around clasts. Macroscopically visible interlayer slips shows postsedimental character of deformations already in hard rock. Senses of movements, direction of lineation and distribution/partition of deformations in the Příbram syncline indicate a logical conclusion about the reverse fault clay character during the earliest phases of movements. Příbram Syncline is by its foundation the consequence of deformation of Clay Fault. N-W wall was dragged along the Clay Fault. Possible compression and reverse fault can be considered only in the Middle Devonian. This movement can be placed in the time between Frasnian and Westphalian. The middle phase of activity corresponds to sinistral strike-slip displacement with a slight rotation and can be classified by the intrusions of Blatná granodiorite on the edge of Tournaisian and Visean. At this time Clay Fault and Závist Fault were the same fault structure. Besides the kinematics of sinistral strike slip fault the rotation is applied (Knížek & Melichar, 2014).

Knížek, M. & Melichar, R., 2014. The Clay and Závist faults – one large strike-slip fault in the east part of Barrandian (Bohemian Massif). *Geologia Sudetica*, **42**, 36–37.



Geological models of Clay Fault phases. 1) first phase: reverse fault; 2) after block rotation second phase: sinistral strike slip fault; 3) Clay Fault cross-cutting by younger oblique faults; 4) third phase: dip-slip fault without possible determine sense of movement.

Rapid cooling and geospeedometry of granitic rocks exhumation from the Central Slovakian Volcanic Field

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Geospeedometry is branch of geology concerned with study of the geological processes rates. The term of "geospeedometry" was introduced by Lasaga (1983) who outlined a technique for inverting chemical diffusion profiles at the rims of minerals to infer cooling rates. Lasaga (l.c.) geospeedometry considered as extension of geothermometry. The practical significance of geospeedometry occurred in geochronology by application of Dodson "blocking temperature" theory for minerals, respectively replacing it by the term "cooling temperature"; in different isotopic systems and specifying these temperatures for a wide range of minerals from high magmatic temperatures ca. 900°C for U-Th-Pb system in zircon to the low-temperature systems approx. 65°C for the (U-Th)/He system in apatite.

Neovolcanites of the Central Slovakian Volcanic Field (CSVF) are indirectly associated with oceanic/suboceanic lithosphere subduction under flysch basin, and this subduction caused metasomatic processes in the overlying mantle wedge. The Miocene calk-alkaline granitic rocks of the CSVF form an integral component of volcanic and hypabyssal rocks exposed in the Banská Štiavnica and Hodruša tract of the CSVF central zone (Hodruša-Štiavnica Intrusive Complex). The massive granodiorites consist of intermediate plagioclase, quartz, K-feldspar, biotite, amphibole, and accessory magnetite, titanite, pyroxene, apatite and zircon. The rock's texture is even-grained and porphyric in marginal parts, locally with mafic microgranular enclaves. These granodiorites have standard values of SiO_2 (59–66 wt. %), higher contents of CaO (3.7–7.0 wt. %), FeO (1.5–4.0 wt. %), MgO (1.2–3.8 wt. %) and lower content of TiO_2 (0.5–1.0 wt. %). Generally, they have enriched Ba (400–900 ppm), Cr (10–45 ppm), V (60–155 ppm), and F (220–800 ppm), whereas values of Sr = 320–540 ppm, Rb = 80–180 ppm and Zr = 103–188 ppm are standard compared to the other Western Carpathians granites (Marsina *et al*., 1999). The age of these granitic rocks has been determined by various methods (K/Ar, Rb/Sr isochrone, and preliminary U/Pb zircon dating) in broad interval 21–10 Ma previously. In this study we apply a combination of zircon U-Th-Pb on SHRIMP together with zircon (U-Th)/He (ZHe), and apatite (U-Th)/He (AHe) dating methods to constrain the emplacement and exhumation history of granitic rocks of the CSVF. A representative sample of diorite from the locality Banky and granodiorite from Hodruša were chosen for this purpose. The U-Th-Pb zircon dating by means of SHRIMP was carried out at the All-Russian Geological Research Institute (VSEGEI) in St. Petersburg; ZHe and AHe dating was carried out at the University of Waikato. Detailed CL and BSE zircon study revealed a presence of magmatic homogeneous and oscillatory-zoned grains typical for I-type granitic rocks without restite cores. Zircons SHRIMP spot ages of the Banky diorite and Hodruša granodiorite gave concordia-intercept ages of ~15 Ma and ~13 Ma, respectively. ZHe and AHe ages from identical samples (diorite and granodiorite) show compatible ages, which are less than 1 Myr younger than corresponding zircon magmatic crystallization ages for both samples. The data thus suggest a simple rapid cooling from magmatic crystallization/ solidification temperatures (ca. 900°C closure temperature of zircon lattice) to near-surface temperatures without subsequent reheating with high exhumation rates close 5 mm/yr and elevated cooling rates from 620 to 430°C/Myr with an average of 492±65°C/Myr. Similar rates are known from the Andes, Japan and Papua New Guinea.

Tracking end of the “Carnian Crisis” and/or Carnian stage in the Western Carpathians

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The “Carnian Crisis” was a major climate change and biotic turnover that occurred during the Carnian stage in the Tethys, documented is successively by: i) a demise of carbonate platforms and reefs, ii) a major faunal and floral turnover, and iii) a significant extinction event affecting conodonts and ammonoids in basinal, shallow-marine and epicontinental facies (Hornung *et al*., 2007). The arid climate was suddenly interrupted by the markedly more humid conditions in the Late Triassic. However, there is long-lasting discussion concerning the upper limit of “Carnian Crisis” and the Carnian-Norian boundary, because the Late Triassic timescale is poorly constrained due largely to a paucity of high-precision radiometric ages that can be related precisely to evident contradictions between biostratigraphic and magnetostratigraphic correlations. Carnian sediments have been studied intensively in the Northern Calcareous and the Southern Alps, from where was named this stage (Mojsisovics, 1869). The Lunz-Formation (LF) German *Lunzer schichten* - represents typical product of “Carnian Crisis” as clastic depositional phase within the marine Reifling intraplatform basin with the type locality in Lunz am See in Lower-Austrian Ybbstal. LF forms the siliciclastic sediments within carbonate sediments of the Middle and Upper Triassic Alpine-Carpathian realm. These rocks are interpreted as marine delta sediments locally with the coal seams, having a thickness up to 350 m. LF is rich in fossil fauna and flora in mudstone layers, which allowed determining their age at the Lower Carnian by Stur (1868). Lunz-Formation in the Central Western Carpathians is presented in Fatricum, Veporicum and Hronicum. Our research was conducted on the samples from famous localities as Remata, Podtureň near Liptovský Hrádok, Homolka in Valaská Belá and Trstín. Petrographically were studied samples described as lithic feldspar-bearing arkosic sandstones. Their mineral composition mainly involved: quartz, K-feldspar and plagioclase in various forms of clastic grains and/or in rock lithoclasts. Muscovite, biotite, chlorite and glauconite occurs in a lesser extent. Fine-grained sericite from weathered feldspars and partly carbonates form matrix. Heavy minerals are represented mainly by zircon, apatite, rutile, pyrite, Cr-spinel, titanite, tourmaline, garnet, xenotime and rarely been identified goyazite. However, monazites are often occurring and their EMP Th-U-Pb ages are in a wide range from 1935 up to 217 Ma, with domination between 500–300 Ma. The separated detrital zircons were dated by means of LA ICP-MS for provenance knowledge. Cathodoluminiscence study showed a variable degree of roundness, we observed zircons with oval shape, and the zircons with perfectly preserved crystallization surfaces exhibiting minimal transport. Obtained zircon ages vary from the Late Archaean (2600 Ma) to the Triassic (216 Ma) with dominating ages between 500–250 Ma and well representative youngest syn-sedimentary zircons concordia age close to 220 Ma. It is evident that the source of clastic material in LF was derived from several sources especially: i) from the recycled Variscan orogeny, ii) from the remote craton - Sarmatia (the southern border of the European Platform) and iii) proximate contemporaneous the Triassic volcanic source. These volcanic rocks are now found from Lombardy in the Southern Alps, through the Bükk Mountains to the Black Sea and Turkey area. Noteworthy, the duration of the “Carnian crisis” and thus an upper limit of the Carnian stage our dating proved to 220 Ma, what is consistent with the recent proposal of Lucas *et al*. (2012).

AMS of Křivoklát-Rokycany Complex, Barrandian

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Cambrian volcanic rocks outcroops in Křivoklát-Rokycany volcanic complex, Barrandian area. A tectonic fault with the NE–SE orientation delimits the complex in the south. Main volcanic body is compound of younger rhyolite zone and older andesite–dacite one. Feeding structure is fulfilled by the Sýkořice Porphyr and it is situated in the NE. The porphyr contains only diamagnetic minerals while volcanic rocks in the complex usually reaches values of magnetic susceptibility in order of magnitudes at least 10^{-5} SI.

A lot of small volcanic centers in ryolitic part have been found. The position of centers does not corespond directly to the tectonic fault boundary complex of NE part. New findings indicate that each hill in ryolitic part in Křivoklát-Rokycany complex could be a small feeding center which stays non eroded due to vertical foliations in feeding centers which make the rock more resistent against weathering.

It was possible to distinguish 3 types of volcanic rocks in the older andesitic part. Ferromagnetic particles are main carriers of magnetic susceptibility of two types and they differ from each other in values of magnetic susceptibility. Paramagnetic minerals control magnetic fabrics of the third type. Different AMS fabrics are most probably related to the changes of viscosity and mineral composition of the rock. The highest degree of anisotrophy with oblate character was found close to the contact of andesites and dacites.

It is hard to find any visible structures in the andesitic part. For that reason, the AMS studies were done and the inner magnetic fabric was possible to observe in the andesitic rocks. In few localities the magmatic foliation and even prolongation of bubbles were visible. That structures representing direction of magma flow were measured and correlated with magnetic lineation. The direction of magma flow was always parallel to the magnetic lineation. Therefore magnetic lineation (K_1) can be considered as magma flow direction and magmatic foliation as magnetic foliation.

Kolářová, K., 2013. Stavba a anizotropie magnetické susceptibility vulkanitů křivoklátsko-rokycanského pásma. MS diploma thesis. Faculty of Science, Masaryk University. Brno

Angra Fria magmatic complex in the Kaoko Belt of NW Namibia – a continuation of the Neoproterozoic Granite Belt in the Dom Feliciano Belt (Uruguay and SE Brazil)?

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Magmatic rocks exposed in the northwestern part of the Coastal Terrane in the Kaoko Belt of Namibia show evidence for two distinct periods of granitoid magmatism. An older suite of intermediate–felsic granitoid rocks with well developed magmatic to solid-state fabric is intruded by granites with no solid-state deformation. The suite intruded a complex of migmatitic metasediments intercalated with amphibolites. U-Pb zircon dating of the older granitoid suite provided ages of 626±11 and 621±8 Ma (2 sigma) for the intermediate magmatic rocks and an age of 619±17 Ma for the deformed granites. Granitic sample of the younger granitoid suite that crosscuts the fabric developed in older granitoids gave an age of 575±12 Ma. Dating of dykes of undeformed diorite that intruded the migmatitic metasediments yielded an age 585±8 Ma.

The ages of the younger granitoids are known also from other large plutonic bodies in the western part of the Kaoko Belt, whereas the ages obtained from granitoids of the older suite are similar to those known for the older granitoid members of the in the Aiguá, Pelotas and Florianópolis batholiths of the Dom Feliciano Belt of Uruguay and southeastern Brazil. The tectonic evolution of the Coastal Terrane correlates well with that of the Punta del Este Terrane of the Dom Feliciano Belt. Accordingly, the finding of ca. 620–625 Ma old plutonic bodies intruded by ca. 575 Ma old granitoids in the Coastal Terrane suggests that the whole Angra Fria magmatic complex could represent the NE continuation of the Granite Belt of the Dom Feliciano Belt on the African side of the orogen.

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Zircon (re)crystallization during short-lived, high-P granulite facies metamorphism (Eger Complex, NW Bohemian Massif)

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The Eger Complex in the northwestern Bohemian Massif consists mainly of amphibolite facies granitic gneisses containing a subordinate volume of felsic granulites. Microstructural changes and modelling of metamorphic conditions for both rock types suggest a short-lived static heating from ~760 to ~850°C at a constant pressure of ~16 kbar, which led to the partial granulitization of the granitoid rocks. Detailed study of the protolith zircon modifications and modelling of the Zr redistribution during the transition from amphibolite to granulite facies suggests that the development of ca. 340 Ma old zircon rims in the granulite facies sample is the result of recrystallization of older (ca. 475 Ma) protolith zircon. This study suggests that the partial granulitization is a result of a short exposure of the Eger Complex metagranitoids to a temperature of ~850°C at the base of an arc/forearc domain and their subsequent rapid exhumation during the Lower Carboniferous collision along the western margin of the Bohemian Massif.

Geochronology of the Najd Fault System: SHRIMP U-Pb zircon data from shear zones of the Neoproterozoic Midyan Terrane (NW Arabian Shield)

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A striking feature of the Neoproterozoic, Pan-African orogen in Saudi Arabia, visible on geological maps and satellite images, is a division of the outcropping rocks into two types of structural domain comprising: (1) anostomosing networks of fault and shear zones of highly deformed and metamorphosed rocks – known as Najd Fault System (NFS), that surround (2) lensoid-shape bodies of less transformed rocks forming low strain domains. The shear zones of NFS are typically narrow – a few km wide – but of considerable strike length, and consist of mylonitic bands that pass into wider zones of gneiss domes and antiforms composed of orthogneiss, paragneiss, meta-volcanic rocks, and mica-schists. In the southern part of the Midyan Terrane (MT), the NFS form a unique structural pattern of N- and NW-trending cross-cutting, strike-slip shear zones, all with steep or vertically dipping lithologies. Structural relationships indicate that the N-trending dextral shears along the Hanabiq Shear Zone (HSZ) are relatively older than sinistral NW-trending Ajajj (ASZ) and Qazaz (QSZ) Shear Zones. To assess the age of deformation along these tectonic tracts a set of zircon SHRIMP U-Pb analyses for meta-igneous and volcanic rocks was performed.

Data from QSZ include: mylonitic meta-diorite (720±3.2 Ma), meta-rhyolite (705.8±3.2 Ma), meta-syenogranite (~706–710 Ma) and meta-biotite granite (691.9±4.4 Ma), all indicating ages of primary, pre-kinematic intrusions subjected to later shearing. Another mylonitic rhyolite shows two different zircon populations: of igneous origin (aged between 693–662 Ma) and of metamorphic origin (600±4 Ma), which indicates time of ductile shearing along QSZ. Results from ASZ comprise: mylonitic meta-diorite (701±10 Ma) and coarse-grained granite-gneiss from Hamadat gneiss belt (687.8±2.6 Ma), both of pre-kinematic character and medium-grained, porphyritic biotite-granite (595.1±3.8 Ma) and weakly deformed coarse-grained granite (587.8±7 Ma) classified as syn-kinematic intrusives. Undeformed, post-kinematic dikes cross-cutting foliated host rocks of ASZ are represented by alkali feldspar granite (569±15 Ma) and the youngest lamprophyre, which yielded rounded zircon population of 573.1±5.2 Ma (possible derived from not-outcropping, deep seated granulites). The dikes are interpreted as bodies emplaced shortly after the cessation of ductile deformation and metamorphism along the ASZ. Samples from HSZ are represented by pre-kinematic metatonalite (714±17 Ma), syn-kinematic, mylonitic orthogneiss (590.5±2.8 Ma) and slightly deformed, post-kinematic pegmatite emplaced at ca 590 Ma.

The presented geochronological data indicate that there is no significant difference in time of deformation between QSZ+ASZ and HSZ and that the peak of ductile shearing along nearly synchronous NFS within MT took place between 600–590 Ma.

Source and tectonic implication of the intermediate to acidic volcanoclasts from Jurassic Neotethyan mélanges

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Clast analysis of a subduction and obduction related sedimentary complex provides essential information about the imbricating continental margin and the overriding ofiolite nappe, both being part of the source area. We examined intermediate to acidic volcanic clasts of three sedimentary melange nappes (Meliata, Telekesoldal, Mónosbél) which were formed during the Middle Jurassic – Early Cretaceous closure of the Neotethys Ocean. Geochemical characteristics of cm to 100m in size rhyolite and andesite clasts were investigated. The REE and Trace-element patterns of all the volcanites are very similar. The light and heavy REEs are relatively well fractionated (LaN/LuN = 2.32–7.69). CI chondrite normalized trace element values show significant enrichment in LILE and lower enrichment in HFSE (20–50-fold). Ta/Yb vs. Th/Yb discrimination diagram refers to within plate volcanism (Gorton & Schandal 2000). U-Pb isotope analyses of zircon crystals by LA-ICP-MS resulted in two age groups: 220 Ma and 206 Ma. Geochemical analysis of potential Middle to Late Triassic volcanic rocks were performed to find the original source of the clasts. As a result, Middle Triassic tuffs and acidic to intermediate volcanites of the Bükk (Dinaridic margin) and the Transdanubian Range (Upper Austroalpine) show almost identical geochemical pattern. In contrast, no significant volcanic activity has been proven on the northern margin of the Neotethys at this time.

The volcanoclast composition of the melange nappes, which thrust over the different margins (N and S) have common source, the Dinaridic and/or Austroalpine margin. While the ofiolite obduction onto the southern margin is proved to be Late Jurassic, only Cretaceous nappe contacts have been documented on the northern margin, although subduction started in the Late Jurassic. It can be interpreted in two ways: either the latest Jurassic to early Cretaceous nappe emplacement dismembered the unique (similar) Jurassic trenches into nappe sheets with different tectonic transport directions, emplaced onto different margins, or alternatively the first accreted Dinaridic melange nappes were partly thrust on top of the northern margin, via backthrusting, during the Cretaceous deformation (Figure).

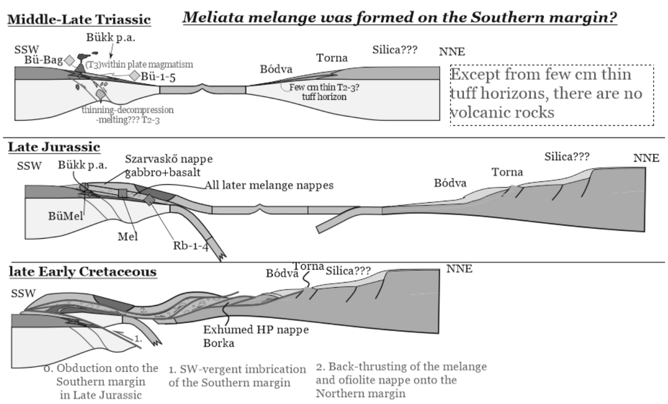

Figure: Possible reconstruction indicating T_3 volcanism, J_3 obduction and C2 back-thrusting.

Distinct deformation microstructures identified in quartzo-feldspathic rocks of different nappes in the Krušné hory Mountains

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The aim of this work is to characterize and evaluate deformation microstructures of quartzo-feldspathic rocks in the central part of the Krušné hory Mountains (Erzgebirge) in the Saxothuringian domain of the Bohemian Massif. The studied area shows large-scale domal structure formed by core consisting mainly of Proterozoic and early Paleozoic rocks represented by garnetiferous micaschist, orthogneisses and rare eclogite bodies in its uppermost part and by mantle consisting of Palaeozoic metasedimentary complexes represented by quartzites, chl-bt micaschists and phyllites. The core of the dome is build by three different units/nappes, from bottom to top the Para-autochthonous unit, the Lower nappe and the Upper nappe, characterized by distinct deformation features, intensity of deformation and metamorphic PT history. The lowermost unit represented by the so called Para-autochthonous unit (Reitzenhain-Catherine) is associated with lower-grade conditions while the tectonically emplaced Lower and Upper nappes show HP(UHP)-MT and HP-HT metamorphism, respectively. The assemblage represents a tectonic crustal stack originating from Variscan subduction and collision of continental crust. The deformation record in the Para-autochthonous unit shows the principal fabric defined by shape preferred orientation of K-feldspar porphyroclasts, which is overprinted by moderately to the south dipping cleavage resulting in subhorizontal east-west trending intersection lineation. The main metamorphic foliation of the Lower nappe is shallowly to moderately dipping to the northwest with intense east-west trending stretching lineation. The Upper nappe shows moderately to the south dipping fabric defined by compositional banding which bears a southeast plunging lineation. Deformation microstructures observed in samples collected from individual orthogneiss bodies in the studied area allowed us to distinguish three distinct microstructure types, (i) Catherine, (ii) Sfings and (iii) Jöhstadt, with their spatial occurrence corresponding to the above-described units/nappes. (i) The Catherine type shows coarse-grained (0.4–2.3 mm) microstructure with nearly idiomorphic shapes of K-feldspar porphyroclasts and small amount of low temperature quartz recrystallization. This microstructure is typical for the Parautochtonous unit. (ii) The Sfings type shows extensive recrystallization associated with formation of monomineralic quartz bands, marked by lobate grain shapes, and fine-grained (0.1–0.4) mixed plagioclase, quartz and K-feldspar bands. The grains in the latter bands show equiaxial grains and lack of preferred orientation. This microstructure is associated with the Lower nappe. (iii) The Jöhstadt type shows recrystallization of plagioclase and quartz with plagioclase characterized by relatively large polygonal grains and quartz exhibiting amoeboidal grain-shapes. The porphyroclasts of K-feldspar are recrystallized along their edges. This microstructure is commonly associated with the Upper nappe. The results of our study showed the correlation of distinct microstructural types with individual nappes recognized in the studied region. Furthermore, as the macroscopic distinction between individual nappes is in some cases impossible, the above-defined microstructural criteria can be applied to precise and/or correct spatial extent of the nappes.

Oroclinal buckling and associated material flow under laboratory conditions

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Recent structural and geophysical observations from central Asia show that the crustal-scale buckling of Mongol-Okhotsk subduction zone was accompanied with heterogeneous thickening of adjacent crust and deformation of lithospheric mantle. In order to simulate complex deformation processes related to oroclinal bending and deformation of surrounding lithosphere we present a complex analogue model of buckling of vertically layered domain which is surrounded by horizontally anisotropic material with fixed boundary conditions.

We used 43/30/4 cm (width/length/height) modelling domain and one sided piston mechanism. Experimental part is formed by several layers oriented along two principal directions for simulation of a space anisotropy of large orogens. Materials and geometry of the model are scaled according to standard analogue modelling principles (Brun, 2002). Upper crustal layer is formed by Fontainebleau sand with specific and well-known material properties (Cagnard *et al*., 2006). Ductile lower crust, surrounding material and vertical “weak” layer are represented by silicone putty. For the most competent vertical layer (buckling controlling layer), we used high viscosity plastic layer which is imaginable as time-dependent boundary condition which is implemented in the central domain part.

We suggest that our model may simulate the folding of Mongol-Okhotsk subduction zone together with ribbon continent and deformation of adjacent oceanic crust during Permo-Triassic convergence. The model is set up to explain mechanical behaviour of surrounding crust, its thickening, horizontal flow and deformation and associated flow of lithospheric mantle. Model domain is fully filled by material for investigation of negative effect of fixed boundary conditions to general flow over a simulated system. Analyses of this model setup effect revealed a complex superposition of Couette and Poiseuille flow across entire domain. Investigation of mantle flow and exhumation, with buckled and pushed-up of vertically oriented layers, is in good relationship with observations from Hangai dome, which is situated directly under the hinge of CAOB megafold, where large gravitational anomaly has been discovered. These simulations also show that how cooperation and superposition of different material flows could imply typical deformation features creation as general trends in a whole shortened sector. The other results are particularly discussed in a frame of current tectonic models of CAOB or in frame of other papers that discussed oroclinal buckling process as possible component of formation of large orogens (i.e. Pastor-Galán *et al*., 2012).

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New structural model of the Kock Fault Zone (Lublin Basin, SE Poland)

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The Kock Fault Zone (KFZ) located in the Lublin Basin (SE Poland) is composite Paleozoic structure consisting of NW-trending steep fault cutting Precambrian basement and Cambrian-Ordovician sedimentary succession, and anticline located above this basement step and developed within the Silurian – Carboniferous rocks. KFZ separates two segments of the Lublin Basin: SW deeper axial part, and NE shallower part entirely located above the East European Craton. On the sub-Mesozoic subcrop map the KFZ is expressed as 90 km long belt of Devonian rocks surrounded by Carboniferous. For our study NE segment of the Opole Lubelskie-Parczew depth regional seismic transect constructed using reprocessed lines acquired in different years (cf. Antonowicz *et al.*, 2003) was used, that was calibrated by several deep wells. Late Carboniferous (Variscan) unconformity separates flat lying Mesozoic and younger strata from the Palaeozoic complex. This complex was deformed during several Palaeozoic tectonic phases and is characterized by different stratigraphy and thicknesses within both fault limbs. Steeply dipping thick suite of Devonian and Carboniferous is characteristic feature for the footwall of the basement fault, while in the hanging wall flat lying Carboniferous is underlain by partly eroded Silurian. Early Carboniferous (Bretonian) regional unconformity is observed at the base of Carboniferous (Krzywiec, 2009; Krzywiec *et al.*, 2014). Thick, incompetent Silurian shales acted as a regional detachment level for development of the Variscan compressional structure developed above the basement fault (step). Cross-section restoration was used to build a kinematic model of the KFZ, and to assess amount of erosion within both segments of the basin, using additional data provided by palaeothickness maps of Modliński (2010). Constructed structural model includes Bretonian activity of the Kock basement reverse fault resulting in formation of fault-related fold within the Silurian–Devonian cover, and then erosion above the hanging wall. Later, SSW–NNE oriented Variscan compression led to development of a compressional structure above the basement step, with its axial part filled by intensely deformed Silurian shales. Cross-section restoration suggests that up to 3 km of Devonian-Carboniferous deposits have been removed from the hanging wall of the KFZ during and after the Late Palaeozoic deformation events.

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On geochemical variability of orogenic peridotites from Bohemian Massif

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We present new whole-rock major- and trace-element geochemical data from various orogenic peridotite bodies throughout the Bohemian Massif. Peridotite samples have been studied in order to complement the database on chemistry of ultramafic rocks data and for possible correlation with microstructural data. Studied locations are Doubrava and Úhrov (Kutná Hora Crystalline Complex), Ždárec, Nové Dvory, Blanský les, Mohelno (Gföhl Unit of the Moldanubian Zone), Zöblitz (Erzgebirge) and peridotites from Saxon Granulite Massif.

The 23 newly analysed peridotites have an ultrabasic character (SiO_2 = 37.4–45.5 wt. %) and a surprisingly narrow range of high values for MgO (32.1–37.9 wt. %) and mg# (86.5–90.7). With respect to MgO/SiO_2 vs. Al_2O_3/SiO_2 plot (Paulick *et al*., 2006), peridotite analyses follow a trend parallel to 'Terrestrial Array' but are systematically offset to somewhat lower MgO/SiO_2 values, perhaps reflecting some silica addition.

Major-element based principal component analysis suggests strong, but independent, variations in SiO_2 and MgO. Variation in MgO is negatively correlated with Al_2O_3 abundances. Despite large variability within the whole major-element dataset, samples from Blanský les and Náměšť stand out as particularly homogeneous clusters, both with somewhat elevated SiO_2 contents.

The spiderplots normalized to Primitive Mantle (McDonough & Sun, 1995) show a contrasting picture. Particularly variable are the peridotites associated with HP–HT granulites in the Blanský les and Saxon massifs. Characteristic is a various degree of enrichment in LILE (Cs, Rb, Ba) and Pb.

The total REE contents in the newly analysed peridotites are not very variable and rather low (ΣREE ranging from < 0.73 to < 11 ppm). Samples both with and without Eu anomalies are present (Eu/Eu* = 0.62–1.32). While the HREE contents are relatively consistent, LREE are more scattered with majority samples slightly depleted if compared with the Primitive-Mantle. Some peridotites can be discriminated based on the Primitive-Mantle normalized REE patterns – e.g. Zöblitz, Nové Dvory: flat patterns around unity; Doubrava: depleted, convex shape, Lu_N ~0.2–0.3; Náměšť, Úhrov: depleted concave shape, Lu_N mostly ~0.8–0.9.

Taken together, the whole-rock geochemistry reflects a complex interplay between the depleted or primitive mantle domains and metasomatic fluids/melts. The picture is further obscured by mobility of elements (especially LILE) during the complex crust–mantle interactions next to the HP–HT granulite massifs and/or subsequent serpentinization.

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Structural pattern of deformation in the Turňa Nappe constrained by fold and cleavage analysis (Western Carpathians)

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The Turňa Nappe is one of the three nappe systems involved in the geological structure of the inner zones of the Central Western Carpathians. This nappe is formed by a system of partial overthrusts and duplexes, which overthrusts the Meliata Unit and is overridden by the Silica Nappe (Rakús, 1996). The Turňa Nappe is cropping out in the southern part of the Slovenské rudohorie Mts., in the Slovak Karst and Rudabánya Mts. Basically it is divided into the Turňa *sensu stricto*, Slovenská Skala (study area), and Martonyi partial nappes (Mello *et al*., 1997). Structural analysis of folds was carried out predominantly in the Lower Triassic Werfen Formation. Measured fold structures are polygenetic and principally belong to two homogeneous groups. The first fold group F_1 is represented by folds that evolved during the compressional tectonic regime with the NW–SE orientation of principal maximum compressional axis (σ_1). F_1 group is characterized by open to isoclinal, partly asymmetric folds with both the north-western and south-eastern vergencies. The bedding planes are usually SE–ward dipping, the NW-ward and subvertical dips are less common. The mesoscopic fold structures in the Slovenská Skala partial nappe are predominantly occurring in the NE–SW trending anticlinal and synclinal hinge zones of large-scale folds. Folding was accompanied by development of axial plane cleavage. This generally NE–SW striking, locally penetrative cleavage formed in fine-grained, low-grade metasedimentary rocks by pressure solution. The cleavage is mostly subvertical to steeply SE-dipping, hence the bedding vs. cleavage angle depends on the position of bedding with respect to the fold axial planes. It appears that the doubly-vergent F_1 folds reflect the direction of thrusting of the Meliata-Turňa accretionary wedge on the Gemer Unit during the Late Jurassic to Early Cretaceous. By contrast, the second group of folds F_2 was activated during the compressional to transpressional tectonic regime with the E–W orientation of the σ_1. It is considered to be younger than the previous F_1 group. The F_2 fold group is represented by less distinct, open to close folds, in places accompanied by the N–S oriented subvertical cleavage.

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Structural geology research of the Sudoměřice Tunnel – the paleostress analysis (Moldanubicum, South Bohemia)

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The study area is located in the central part of the Moldanubicum, in the Variegated Unit. It is bordered by the Mid-Bohemian Plutonic complex in the west. Data were collected from new Sudoměřice tunnel excavation, recently excavated outcrops and natural outcrops tunnel construction surroundings. Double track Sudoměřice tunnel is part of the Tábor – Sudoměřice u Tábora railway track section of 4th railway transit corridor Praha – České Budějovice. The tunnel with total length of 444 m is built with use of NATM method. The tunnel excavation proceeded through biotite-sillimanit paragneiss and migmatite with sporadic fine-grained aplite intrusions. Paragneiss and migmatite are medium to fine-grained with distinctive E–W foliation dipping 10–30° to the north. Rock was variously altered along faults and joints. Similar geology was documented in other studied localities (old track cuts, recently excavated cuts for new track, excavated outcrop for new underpass to Sudoměřice station, outcrops west of Prudice, near D3 motorway, and Moraveč). Outcrops situated near Borotín are formed in granitiod intrusion. Most of outcrops showed slight variations in measured foliation.

Faults, striations orientation and kinematics from the tunnel and outcrops were processed by updated version of MARK 2011 software (Kernstocková, 2011). Results of paleostress analysis showed heterogenouse origin of dip-slip faults and three dominant phases. Phase one main compression axis (σ_1) plunges 24° to the NE whereas relative extension axis (σ_3) moderately plunging to the west. Characteristics of phase two are σ_1 plunging 29° to the ESE and sub-vertical σ_3 trending to the NW. Phase three has distinctive subhorizontal σ_1 trending to the NNW while σ_3 is moderately plunging to the WSW. Faults corresponding to determined stress axis were separated using MIM Package (Yamaji & Sato, 2005). On the basis of Anderson's theory, normal and reverse faults fitted to phase one and phase three while phase two matched only normal faults. Most of faults fitted to phase three stress axis.

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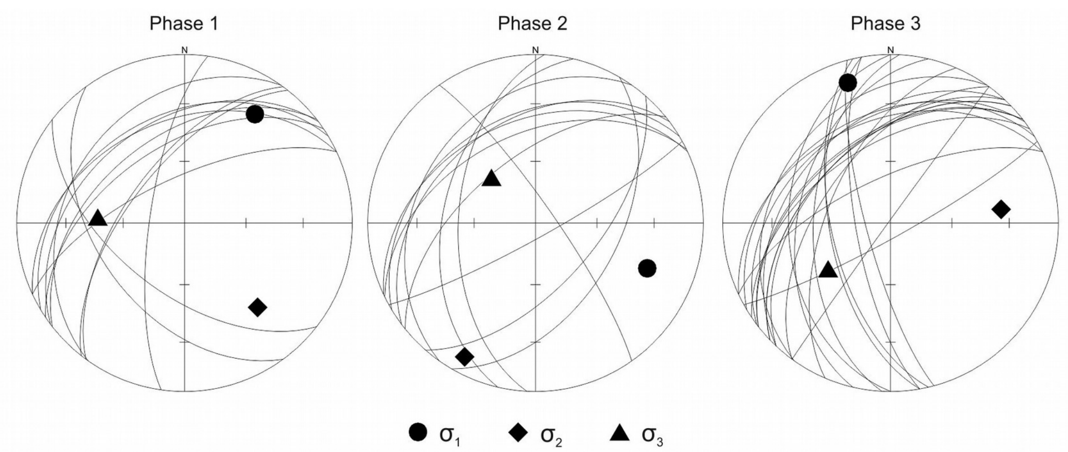

Three phases with main stress axis σ_1, σ_2 and σ_3 were determined from paleostress analysis of faults and striations measurement from the Sudoměřice tunnel excavation and its surroundings.

Radiolaria species present on a locality in the Čoltovská roklina ravine – final results

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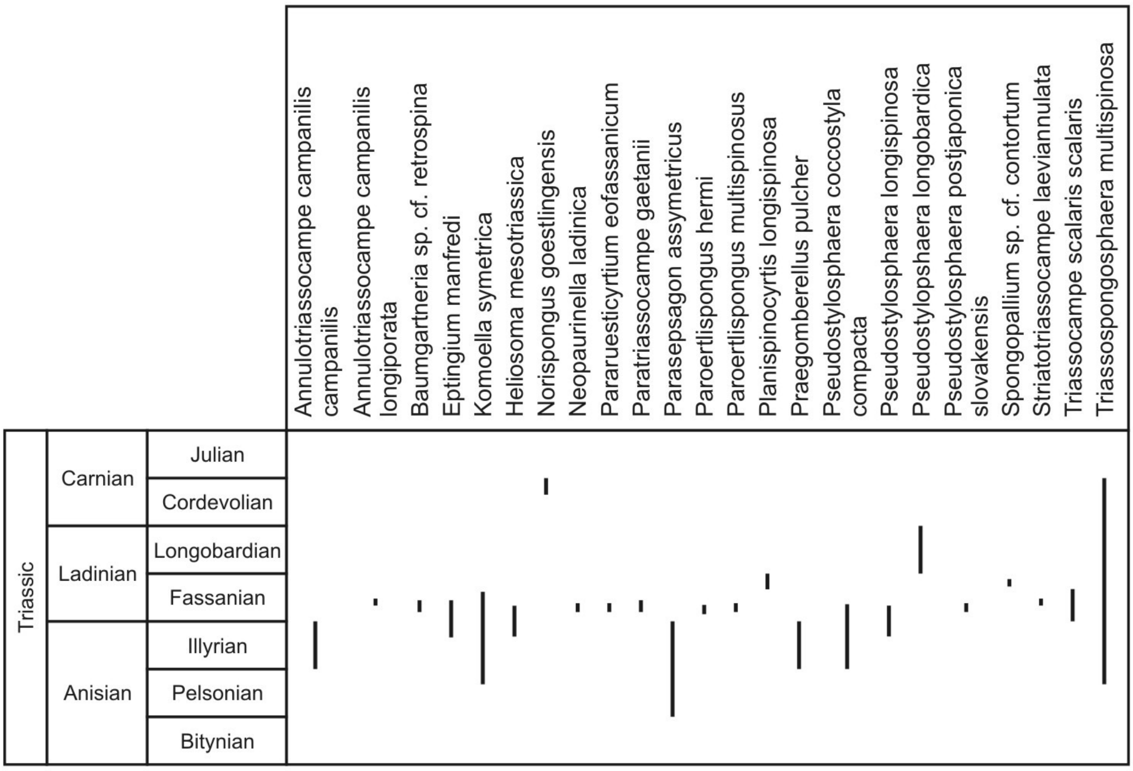
A total of fourteen samples were taken from an old radiolaritic quarry in the Čoltovská roklina trough, and the surrounding area. All samples were dissolved by use of several dissolution methods, which are able to separate radiolaria from radiolarites. Overall, while every dissolved sample was radiolaria positive, sufficient identification markers for species identification were preserved only in half of the total number – seven samples. Altogether, we identified 23 radiolarian species (Figure) with the main stratigraphic range of Illyrian-Fassanian (Kozur & Mostler, 1981, 1994; Kozur *et al.*, 1995). While seven of the taken samples came from seemingly successive beds in the wall of the quarry remnant, stratigraphic range of the radiolaria separated from them was the same for every sample. As such, it can be concluded that these beds cannot be viewed as older and younger based on their stratigraphic position.

Kozur, H. & Mostler, H., 1981. Beiträge zur Erforschung der mesozoischen Radiolarien. Teil IV: Thalassosphaeracea Haeckel, 1862, Hexastylacea Haeckel, 1882 emend. Petruševskaja, 1979, Sponguracea Haeckel, 1862 emend. und weitere triassische Lithocycliacea, Trematodiscacea, Actinommacea und Nassellaria. *Geologische und Paläontologische Mittleilungen Innsbruck*, **1**, 1–208.

Kozur, H. & Mostler, H., 1994. Anisian to Middle Carnian radiolarian zonation and description of some stratigraphically important radiolarians. *Geologische und Paläontologische Mittleilungen Innsbruck*, **3**, 39–255.

Kozur, H., Mock, R. & Ožvoldová, L., 1995. The age of red radiolarites from the Meliaticum of Bohúňovo (Slovakia) and remarks to the Anisian-Ladinian boundary. *Mineralia Slovaca*, **27**, 153–168.



Tectonic classification of the southern Bohemian Massif according to the Tectonic Data Set of the Geological Survey of Austria (TDS)

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The southern part of the Bohemian Massif is composed of the Moldanubian and Moravian Superunits of the Variscan Orogen. Their thrust contact and a supposed internal nappe-like structure has been known since Suess (1912, 1918). However, the real extent of the nappes came obvious in the course of mapping campaigns of the Geological Survey of Austria in the sixties and seventies. The resulting controversial geological models were intensely discussed (e.g. Fuchs, 1976; Matura, 1976; Thiele, 1976; Tollmann, 1982; Fritz & Neubauer, 1993).

The tectonic subdivision of the southern Bohemian Massif according to the TDS is as follows: The Bohemian Massif today is part of the Eurasian Plate, which has been overthrust by the Alpine Orogen from the south. The easternmost part consists of the Brunovistulian Superunit approaching the Austrian border from southern Moravia. This superunit formed the foreland of the Variscan Orogen, which was consolidated during the Cadomian Event. The Moravian Superunit represents also a part of this foreland, incorporated into the Variscan Orogen in a late stage. This superunit is subdivided into the Thaya and Svratka Nappe Systems. The Moldanubian Superunit contains several nappe systems (from bottom to top it is Ostrong, Drosendorf and Gföhl Nappe Systems) which have been intruded discordantly by the extensive South Bohemian Batholith. In the southwestern Bohemian Massif due to syn- to postmagmatic deformation and contemporaneous high-temperature metamorphism a new independent tectonic superunit formed out of former nappe systems referred as Bavarian Massif. During the late stage of the Variscan Orogeny, already in the late Carboniferous, NW–SE and SW–NE trending strike slip-faults evolved. Being active until the early Permian they were linked with the formation of graben structures. Basins filled with Late Cretaceous sediments are also prominent tectonic features. All the faults and basins were reactivated by the Alpine Orogeny, especially in Miocene time. The TDS was established in the course of the compilation of different data sets in order to generate the Maps of the Federal States of Austria in scale 1:200000. Subsequent to the publication of the individual maps a combined data set was created and completed, updated, harmonized and separated in different feature classes: bedrock, late Paleogene to Neogene basins, Quaternary, and geological structures. Now these feature classes can be viewed separately or in any combination. Within the feature classes the contents are ordered by tectonic, lithostratigraphic, lithologic and chronostratigraphic attributes. The tectonic attributes are grouped into classes: lithospheric plate/active orogen, tectonic superunit, tectonic unit, nappe system, nappe, subnappe. The fundamental tectonic unit is the nappe which is considered an allochthonous body of rock transported along a discrete fault-plane (thrust) on top of other units. The higher-ranking nappe system is composed of several nappes which originated from neighbouring paleogeographic realms and shared a common tectonic history over a certain geological time period. Maps with different scales and grades of detail can be generated from the TDS. The accompanying legend is retrieved automatically from a proven collection of units. This array of terms is a representation of the complete tectonic legend of Austria at the same time. Generally this tectonic classification was motivated by the INSPIRE Directive (2007/2/EC) for establishing an Infrastructure for Spatial Information in the European Community.

Cavitonics: how to use caves in neotectonics (introduction of a new method)

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The Pliocene and Quaternary caves can reveal a lot about the neotectonics in suitable regions. Territory of Slovakia offers such possibilities with extensive carbonate sequences and abundant caves. The fact that many cave spaces are situated on a brittle tectonics structures is well-known in the field of speleology, yet in structural geology caves are rarely used as a tool for the study of tectonics. As in work of Hancock *et al.* (1999) the term travitonics was established for study of active tectonics using travertines, cavitonics is proposed as a name of this novel method, which uses caves for the study of neotectonics. The Pliocene and Quaternary cave passages represent geologically one of the youngest structures, and their orientation generally corresponds with the coeval or younger brittle structures reflecting tension oriented generally perpendicular to the walls of passages. The method is based on morphology, orientation, and deformations analysis of the solutional cave passages with purpose to obtain the main extension orientation of the stress field in the Western Carpathian realm. The results established a link between orientation of the main extension obtained from published structural data and cavitonics. In the western and central part of Slovakia, the extension was oriented NW–SE to N–S direction during the Pliocene – ?Early Pleistocene. During the ?Late Pleistocene – Holocene, the orientation of the extension changed in direction NE–SW to E–W. Cavitonics represents a versatile supplementary method, which should be used in concert with other neotectonic methods; however it can also provide solid results when used as a stand-alone method. Depending on the approach, the method can be used for rapid assessment of the stress field orientation, but with greater time investment it can also serve for more detailed studies of the stress field evolution.

Hancock P. L., Chalmers R.M.L., Altunel E. & Çakir Z., 1999. Travitonics: using travertines in active fault studies. *Journal of Structural Geology*, **21**, 903–916.

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Deformation record in an orogenic peridotite body of the St. Leonhard granulite massif

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An orogenic peridotite body enclosed within felsic granulites of the St. Leonhard granulite massif of the Bohemian Massif has been studied in order to identify the internal strain fabrics and evaluate strain coupling. The studied peridotite forms an E–W elongated narrow body within HP granulites composed dominantly of felsic rocks with metamorphic assemblage of Kfs+Qtz+Grt+Ky±Bt±Plg and subordinate intermediate to mafic varieties (Grt+Cpx+Plg+Qtz ±Opx±Bt). In the granulite massif and its surrounding two orientations of subvertical foliation is documented: E–W trending in the central part of the granulite (in the vicinity of the peridotite body) and N–S trending in the surrounding mostly mid-crustal rocks. Vertical fabrics are overprinted by subhorizontal mylonitic foliation bearing strong E–W trending stretching lineation. The forming P–T conditions of the later foliation were estimated to 750°C and 8 kbar in all the lithologies, while the peak conditions that may be related to the vertical fabric are ~900°C and 15–20 kbar in the granulite and ~700°C and 10 kbar in the surrounding mid-crustal rocks.

The microstructural study revealed two distinct microstructural peridotite types. One is coarse grained garnet peridotite, composed of forsterite (X_{Mg} = 0.88), diopside (X_{Mg} = 0.90–0.92, Jd = 8–14%, CaTs = 0–3%), enstatite (X_{Mg} = 0.89) and zoned garnet (X_{Mg} = 0.81→0.72, Alm = 16→23%, Prp = 68→59%, Sps = 1→2, Grs = 12%) occasionally with spinel inclusions. Garnet is partially or totally replaced by symplectites (kelyphites, Sp+Amph+Cpx+Opx). The crystallographic preferred orientation (CPO) is characterized by axial (010) pattern in olivine, S-type <001>(010) pattern in diopside and <001>(100) pattern in enstatite. The CPO patterns show in coarse grained microstructure type subvertical E–W trending foliation with subhorizontal lineation. The foliation is also marked by elongation of olivine and pyroxene crystals. The second microstructural type is finer grained with matrix composed of forsterite (X_{Mg} = 0.91), diopside (X_{Mg} = 0.93–0.95; Jd = 4–9%; CaTs = 0–2%), enstatite (X_{Mg} = 0.91) and spinel, where pyroxene-rich bands alternate with those composed of olivine. Garnet is totally replaced by kelyphites (Sp+Amph+Cpx+Opx). Olivine, pyroxene and spinel crystals as well as kelyphites are elongated parallel to the deformational fabric. The CPO in the second microstructural type revealed axial (010) and A-type pattern in olivine, <001>(010) pattern in diopside, <001>(010) pattern in enstatite and subvertical N–S trending foliation.

The two observed orthogonal subvertical fabrics are parallel to the older foliations described in the area: E–W trending subvertical foliation with E–W lineation in the granulites (i.e. coarse-grained texture with garnet) and N–S trending subvertical foliation in the mid-crustal rocks (i.e. mylonitic texture with spinel). The subhorizontal foliation dominant in the area is entirely lacking in the peridotite body. These observations may bring new view on the evolution of the observed steep fabrics with contrasting orientations in the eastern margin of the Bohemian Massif. The E–W trending foliation may represent earlier stage connected with onset of exhumation of the rocks from mantle/lower-crustal conditions. The N–S trending foliation developed already in lower to mid-crustal conditions may represent localization of deformation responsible for N–S trending foliation in surrounding less competent mid-crustal units.

Bohemian granulites: effect of Zener pinning on grain size evolution and deformation mechanisms

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We numerically simulate the interplay betwen grain size and deformation with the aim to interpret a sequence of microstructures recorded in the felsic granulite massifs in the southern Moldanubian domain (Bohemian Massif, central European Variscides). These massifs were interpreted to result from collision-related diapiric ascent of lower crust followed by lateral spreading at mid-crustal levels. Three types of microstructures associated with distinct deformation fabrics were distinguished. The oldest relict microstructure (S_1) with large grains (>1000 μm) of feldspar deformed probably by dislocation creep at peak HT eclogite facies conditions. Subsequently at HP granulite-facies conditions, recrystallization of feldspar porphyroclasts led to development of a fine-grained plagioclase and K-feldspar granulitic matrix (S_2, ~50 μm grain size). Very weak lattice-preferred orientation and random distribution of phases in the S_2 microstructure indicate deformation via diffusion creep, probably assisted by melt-enhanced grain-boundary sliding. The subsequent switch to the S_3 microstructure (~100 μm grain size, dislocation creep, amphibolite-facies conditions) was interpreted to be related to a significant strain rate decrease.

In order to calculate the mean grain size at given conditions we applied a thermodynamics-based approach which can take into account hindering of grain growth due to Zener pinning in a two-phase matrix. For conditions compatible with the S_1 and S_2 microstructures (~800°C and strain rate ~10^{-13} s^{-1}) the calculated grain size with Zener pinning is significantly smaller (~10x) than in a single-phase model. This is in agreement with the contrasting grain sizes associated with the S_1 and S_2 microstructures, and it shows that the recrystallization of S_1 feldspar porphyroclasts must have played a fundamental role in the transition to the diffusion creep associated with S_2. The model with pinning also explains only minor changes of the mean grain size associated with the S_2 microstructure despite the elevated temperature. The S_2-S_3 switch from the grain-size-sensitive creep to dislocation creep is difficult to explain when assuming reasonable temperature and strain rate. However, a simple incorporation of the geologically meaningful effect of melt solidification into the model can mimic this switch. Besides that we consider the observed decrease of the number of mineral phase contacts and increase of “like-like” contacts in the S_2 microstructure during deformation. In the model, it corresponds to a decrease of Zener pinning efficiency accompanied by coarsening and finally a switch to dislocation creep.

In the applied equations, the resulting grain size and associated deformation mechanism (dislocation or diffusion/grain size sensitive creep) depend on many parameters, some of which are poorly constrained. We discuss the influence of these parameters in the resulting geodynamic model and compare the modelling results with the geological observations.

Tectonic studies of igneous rocks in metabasite zone and diorite belt in Brno massif

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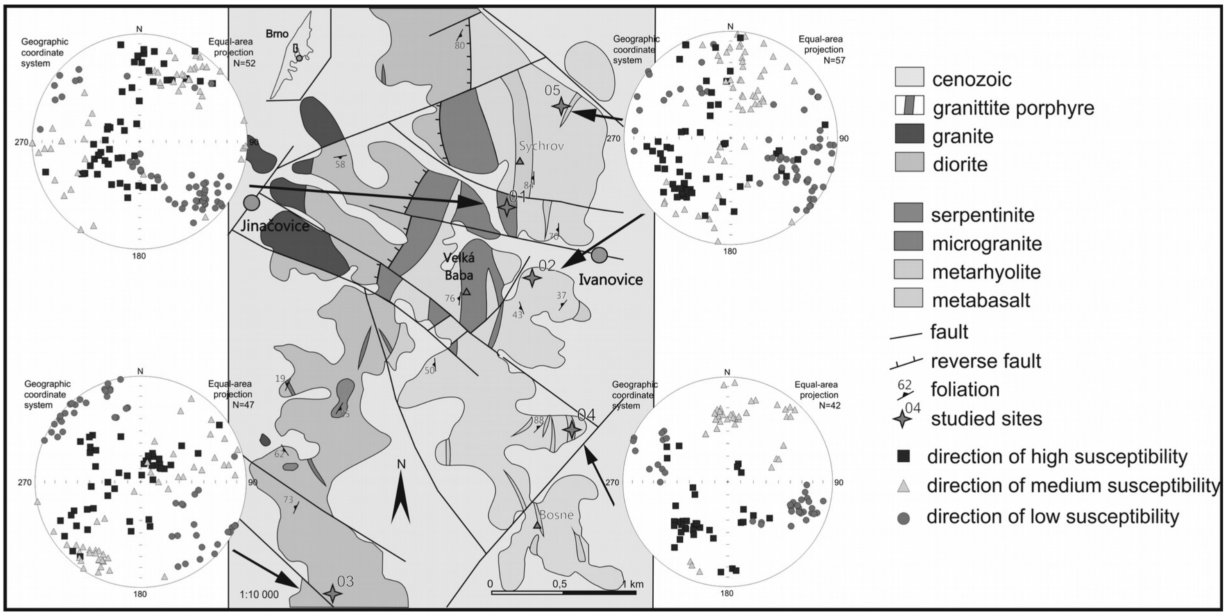
Studied area is situated in Brno massif. The metabasite zone and diorite belt (sensu Hanžl & Melichar, 1997) outcrops in the central part of the massif between two granodiorite complexes. Boundaries between rocks could be easily identified in this area. The metabasite zone consists mostly of low metamorphosed basalt and rhyolite dyke. There is the most common types of rock diorite with small bodies of serpentinite in the diorite belt. There is also some special microgranite on the boundary between metabasite zone and diorite belt found by Hanžl & Hrdličková (2011).

Anisotropy of magnetic susceptibility (AMS) method was used to try to explain the tectonic relations between rocks in this area. The most frequent fabric has strike of magnetic foliation planes in NE–SW direction with steep dip oriented mostly to the NW and magnetic lineation developed in N–S directions (Figure). That trend can be recognized across all the studied area. That could be a proof of sinistral strike slip in Brno massif described by Hanžl & Melichar (1997).

There was also used an analysis of temperature dependence of magnetic susceptibility. This method showed that all fabrics in all rocks in this area are essentially controlled by magnetite with a very small contribution of pyrhotite and hematite.

Hanžl P. & Hrdličková K., 2011. Výskyt mikrogranitu s granofyrickou strukturou na hranici dioritové a metabazitové zóny brněnského masivu východně od Jinačovic. *Geol. výzk. Mor. Slez.*, Brno 2011/2, 128–133.

Hanžl P. & Melichar R., 1997. Brno Massif: a section through the active continental margin or composed terrane? *Krystalinikum*, **23**, 33–58.



Localization of studied rocks between Brno – Ivanovice and Jinačovice with an AMS diagrams.

Electronic examination from structural geology

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Since the electronic age is on the rise, we are trying to keep the pace with the world and that is why at Masaryk University in Brno, there is a possibility of electronic examination. So how do these exams look like? It is an application in university´s Informational System (IS), which contains series of questions based on particular topics. These questions have multiple possible ways to answer them. For example select answer (checkbox, radio-button), fill in the text, fill in one word, fill in number and more... These series of questions are accessible in questionnaires called ROPOTs (Revision, Opinion Poll and Testing). Set of these questions is generated and forms the actual test.

On the exam day, students log into their IS account, they open the ROPOT questionnaire, in which the IS sets unique combination of questions for each apprentice. After completing the questionnaire, IS automatically evaluates the test, marks the wrong answers and shows the right ones, so the student knows the outcome of his test immediately. This system is not used only to examine the knowledge but also to exercise and for preparation/to prepare for the upcoming exam.

IS can generate from questions with multiple possibilities to answer, to questions where you have to fill the right reply. Questions with one-word/number answer seem to be the best ones, because they require active knowledge of the subject. Also, seemingly complicated tasks such as compass measuring, reading from azimuthal projections and relations between structures and stress states can be tested. Past few years of experience of electronic examination have brought positive outcomes in improving the level of students' knowledge.

Do not be shy and try it on: http://goo.gl/ADnDVL

Subsidence and thermal history of the Tlumačov-1 borehole

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The one dimensional model (1D) of thermal history and subsidence of the Tlumačov-1 borehole was created in order to determine the thickness of missing units. The reliability of the model was verified by using vitrinite reflectance Rr [%] as calibration parameters.

Studied borehole is located in the prospection area Vizovice Hills in the eastern part of the Czech Republic. Borehole Tlumačov-1 hit crystalline basement called brunovistulicum, covered with autochthonous Carpathian Foredeep represented mostly by claystones and sandstones. Allochthonous sequences are present as overthrusted Pouzdrany unit formed by marls and shales, shales of Submenilitic Fm. and Ždánice-Hustopeče Fm. formed by alternating calcareous shales and sandstones. Total drilled depth reached 2,315 m.

The numeric model calculates the heat transfer through lithological layers with temporally changing porosity and thermal conductivity. Thermal maturity of organic matter as a manifestation of the total thermal history is calculated using chemical kinetic algorithms for vitrinite reflectance. This tool is applied to calibrate the alternative scenarios of paleo-heat flow and thickness of the eroded units. The borehole Tlumačov-1 has specific maturation trend with depth and each individual nappe has own geothermal gradient and has to be modelled independently (Hantschel & Kauerauf, 2009; Gusterhuber *et al*., 2013). The used heat flow (HF) scenario during strata sedimentation respects published geological concept presented in Pícha *et al*. (2006). Heat flow values stars with 78 mW/m^2 for Devonian rift, followed by continuous cooling up to Neogene. The cooling was increased due to Carpathian nappes thrusting and recent calculated HF values are 35 mW/m^2.

The final model represents the gradual thrusting of the Pouzdřany and Ždánice nappe on the basement of Neogene rock during last 16 Ma. The comparison of modelled and measured data provided good fit.

Hantschel, T. & Kauerauf, A. I., 2009. Fundamentals of Basin and Petroleum Systems Modeling. Springer, 131–148. Berlin.

Picha, F., Stráník, Z. & Krejčí, O., 2006. Geology and Hydrocarbon Resources of the Outer Western Carpathians and Their Foreland, Czech Republic. – In: Golonka, J. & Picha, F., eds, 2006. The Carpathians and Their Foreland: Geology and Hydrocarbon Resources. *AAPG Memoir*, **84,** The American Association of Petroleum Geologists. 49–175.

Gusterhuber, J., Hinsch, R., Linzer, H-G. & Sachsenhofer, R. F., 2013. Hydrocarbon generation and migration from sub-thrust source rocks to foreland reservoirs: The Austrian Molasse basin. *The Austrian Journal of Earth Sciences*, **106/2**, 115–136.

Two stages of blueschists exhumation in the Western Carpathians constrained by the sedimentary age of their erosional products (Klape Unit, Pieniny Klippen Belt)

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The Cretaceous conglomerates of the Pieniny Klippen Belt contain pebbles of variable sedimentary, magmatic and metamorphic rocks. The HP/LT, blueschist-facies metamorphics are represented by: 1) pebbles of Upper Jurassic glaucophanites in the Albian–Cenomanian Upohlav-type conglomerates of the Klape Unit; and by 2) terrigenous clastic admixture in the Barremian–Aptian shallow-water, Urgon-type bioclastic limestones that also occur as pebbles in the Upohlav conglomerates. We are presenting results of our study of limestone pebbles.

In the limestone pebbles, we have identified benthic foraminifera of genus *Orbitolina* and planktonic foraminifera of genus *Hedbergela* (both ranging from Barremian to Cenomanian), as well as fragments of reef-building bivalves, echinoid particles, algae, corals and other shallow-water organisms. Lithoclasts are represented by glaucophanites, serpentinites, HP/LT phyllites, amphibolites, acid and mafic volcanites, sandstones, quartzites and carbonates older than Barremian. Detrital minerals include sodium amphibole, paragonite, muscovite, garnet, chloritoid, allanite, spinel, rutile, calcium amphibole (titanium magnesio-hastingsite), quartz, albite, tourmaline, zircon, biotite, chlorite and barite. According to their composition, the sodium amphiboles belong to the glaucophane – ferro-glaucophane series. Composition of detrital white micas complies with the complete substitution series of K-Na micas with muscovite and paragonite as the end members. Paragonite forms centres of mica flakes replaced by muscovite in the rims. Chemistry of garnets indicates their provenance from: 1) low-grade metasediments (phyllites); and 2) from serpentinites. The composition of spinels corresponds to the chromite – magnesio-chromite series. The oldest possible Barremian stratigraphic age of limestone pebbles and their present position in mid-Cretaceous flysch deposits point to two significant tectonic stages in evolution of the Western Carpathians. The first age constrains the start of exhumation and erosion of blueschists before the Barremian, the latter age indicates erosion of blueschists-bearing limestones and deposition of their pebbles in mid-Cretaceous flysch deposits. These two events are indirectly corroborated also by the EMPA dating of monazite from HP/LT phyllites of the Meliatic Bôrka nappe (Méres *et al.*, 2013), the possible source of blueschists. The monazite age group 147±17 Ma is in line with the first occurrence of blueschists detritus in platform carbonates, whereas the younger age 89±18 Ma likely registers the collision and nappe stacking processes in the inner Western Carpathian zones. Thus the lower limit of the latter age span is coeval with the first common occurrence of blueschist pebbles and pebbles of the now completely destroyed Urgon-type carbonate platform containing the blueschist clastic material in the Albian conglomerates.

Méres, Š., Ivan, P., Konečný, P., Aubrecht, R., Sýkora, M., Plašienka, D. & Reichwalder, P., 2013: Two monazite ages from the accretionary prism mélange of the Meliata Ocean (Bôrka Nappe, Meliatic Superunit, Western Carpathians). GEEWEC 2013, Geol. Inst., SAV, p. 62.

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3D model of the base of the Doupovské hory Volcanic Complex

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The Doupovské hory Volcanic Complex (DHVC) represents remnants of the Cenozoic alkaline volcanic activity in the Eger Graben area. It is located on the contact between two regional units: Saxothuringian Zone (on the north) and Bohemian Unit (on the south). The volcanic rocks are estimated to be up to 300 meters thick. The borehole coverage in the Doupov Mts. area is highly non-uniform. Boreholes are concentrated in several research territories, which are recognized for minerals or mineral water. About 770 boreholes have been analysed during geological mapping. Most of them were terminated in the volcanic complex. The maximum thickness of volcanic rocks is 192 meters in the borehole JD65 near Mořičov and more then 200 meters in the unlisted and unfinished borehole DB-3 (?) in Doupov. It follows from a preliminary evaluation that differences in the altitude of the base of the Doupovské hory Volcanic Complex exceed previously detected and estimated thicknesses. This difference is remarkably high along the Střezov fault, where the base of DHVC reaches 500 meters a.s.l. edgewise, while it is -100 meters b.s.l. at the base of the fault scarp under the Cenozoic sediments of the Pětipsy Basin. The difference in altitude of the base of the DHVC exists also along the fault in the Liboc creek valley, which limits (as the Střezov fault) the area of the Upper Palaeozoic basin in the basement. For larger parts of the Doupov Mts. area, the base of the volcanic rocks is about 300 meters a.s.l. It exceeds 500 meters a.s.l. only in the south margin of Doupov Mts. where a newly defined unit of the younger scattered alkaline volcanic field joins the Doupov volcanic complex.

Geophysical and geological significance of the contact between Saxothuringian Zone and Teplá-Barrandian Unit known as the Litoměřice Fault

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The Litoměřice Fault (LF) was defined by Röhlich & Štovíčková (1968) on the basis of the density boundary (gravity gradient) in the gravity field between Saxothuringian Zone (SXT) and Teplá-Barrandien Unit (TBU). They presumed as a boundary the existence of the deep seated fault. LF was placed in the position of very steep gravity gradient. Kopecký (1974) designated as LF the southern limit of the Ohře rift and shifts it more southwards. Both authors defined the dip of LF to the NW. Thereby the LF got a double meaning: firstly as fault on the contact between two geological units and secondly as marginal fault of Ohře rift.

The correlation and interpretation of boreholes by Mlčoch (2001) provided new information about crystalline basement of the Doupovské hory Mts. and North-Bohemian Basin. He defined location of the contact between SXT and TBU on the relief of the crystalline basement buried beneath Cenozoic, Cretaceous and Permo-Carboniferous sediments. In some areas (e.g. in SW part of České Středohoří Mts.) the difference between geological and density boundary reached up to several tens of kilometers. It follows that contact SXT and TBU falls initially at a slight angle to the NW until only in place of the gravity gradient falls steeply. This trend is the opposite from what was found in the 9HR seismic reflection profile (west of the Doupovské hory Mts.).

The collisional zone between SXT and TBU can no longer be referred to as fault (originally as LF). Character of the collisional zone SXT and TBU was established also by deep seismic refraction survey. Novotný *et al*. (2009; 2010) interpreted S01 and S04 profiles and correlated velocity models with gravity and geology. The LF as the southern limitation of Ohře Rift was discussed by Cajz *et al*. (2006). These authors also identified and reinterpreted faults of the rift structure and they left the term LF.

Extreme geochemical variability of leucogranites at the margin of the Granulite Complex of Southern Bohemia

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Granites of this Moldanubian domain include leucocratic types with muscovite or with muscovite and biotite, and types with biotite as the single mica. Tourmaline- and garnet-bearing granites are somewhat less common. In investigating intrusion form, it is practical to record a) minor dykes, less than 10 m wide, b) dykes 10–200 m wide,and c) irregular intrusions (> 200 m). Geochemical data indicate a specific and complicated grouping largely independent of the dyke size or a simple petrographic classification. The set of 25 samples characterizes 20 dykes and small intrusions in various partial units in the Bohemian Forest, such as granulites, the Monotonous and Varied Unit and the durbachite pluton. Based on normative calculated compositions (granite mesonorm with biotite, Janoušek *et al.*, 2006), the samples are classified as alkali-feldspar granites (plagioclase $An_{0–5}$) and calc-alkali granites ($An_{5–18}$). The Ba–Sr–Rb ratio provides an additional measure of the differentiation process. The relatively Rb-rich samples are typical of alkali-feldspar granite compositions. Based on the contents and distributions of the REE normalized contents several types of REE patterns can be distinguished: (a) granites with a prominent Eu anomaly; (b) granites free of a prominent Eu anomaly; and (c) granites with a clear tetrade effect in the distribution of normalized REE values; this effect indicates the role of H_2O-rich fluids or the activity of fluorine (Irber 1999).

Tourmaline granites (± Ms, Grt) contain schorl with 20–40 mol. % dravite. According to the Na–Ca–vacancy classification, the compositions correspond to Na-schorl with ca. 30 % vacancies. Garnets contain only almandine and spessartine as their major components (ca. 30 mol. % Sps) but a sample from the Hrad hill exhibits an outer zone containing up to 30 mol. % Grs. Apatite occurs in several generations, especially in alkali-feldspar granites, which have a significant phosphorus substitution in feldspars: 1) primary fluorapatite, 2) minute anhedral apatite (containing P unmixed from albite) contains up to ca. 10 mol. % of chlorapatite component in the predominating fluorapatite, 3) very rare (hydrothermal) hydroxylapatite filling brittle fractures in tourmaline. Accessory cordierite, originally present in some leucogranites, is altered to pinite (muscovite+chlorite±biotite aggregate). Several samples from the Smrčina map sheet contained cordierite with low Be (up to 38 ppm Be in the whole-rock), which is now present in newly formed tiny beryl in pinite.

The set of 25 leucogranite samples from the area exhibits surprising geochemical and mineralogical heterogeneity, suggesting high variability during the magma formation and mixing and also in the manner of magma emplacement. Full evaluation of the data remains to be completed.

Contractional modification of the back-arc rift system; Eocene–Quaternary Black Sea case study

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Structural data from onshore outcrops, offshore wells and seismic profiles together with published data on orogenic activity indicate that the spatial and temporal development of the Greater Caucasus, Lesser Caucasus, Eastern Pontides, Western Pontides and Balkans from the Oligocene to the Recent controlled flexural behaviour of the plate underlying the Black Sea, its sediment entry points, distribution of sediment provenances, sediment transport pathways and geometries of fan systems.

This effect included actively thickening orogenic regions encroaching on the Black Sea representing spatially and temporally varying system of loads flexing the Black Sea crust, their uplifting regions representing areas of accelerated erosion, associated positive relief features serving as sediment transport dividers, orogenic re-entrants and other lower portions of orogenic relief and axes of foreland basins capturing sediment entry points into the basin, and spatially and temporally changing forced flexing of the Black Sea crust controlling the geometries of its fan systems.

The youngest orogenic events responsible for the present-day shape of the Balkans took part during Middle Eocene–Oligocene. The main geometry of the northern portion of both Western and Eastern Pontides shaped during Eocene–Recent. The main orogenic events controlling the Lesser Caucasus load distribution happened during Eocene–Early Miocene. The youngest orogenic events responsible for the present-day shape of the Greater Caucasus took part during Late Miocene–Recent.

A combination of orogenic activity maps with basin floor dip maps of the Black Sea including some interpreted fan shapes indicate that the time interval of forced flexing of the Black Sea crust started in Eocene and ended in Pliocene, coeval with the onset of the lateral extrusion of the Anatolian wedge.

Geochemical characteristics of the Triassic volcanic horizons in the Bükkium (NE Hungary) with structural implications

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The successions of the Bükk Mts (NE Hungary) ranging from the Upper Carboniferous up to the Jurassic comprise several rock bodies of volcanic origin. The rocks were subject to low-grade metamorphism and polyphase ductile and brittle deformation. There are at least 3 different horizons (Szentistvánhegy Metaandesite [SA], Bagolyhegy Metarhyolite [BR] and Szinva Metabasalt [SB]) constrained by their Triassic sedimentary frame and classified as stratigraphic units, but a number of small-scale bodies are of ambiguous stratigraphic place.

Chemical assays including REE-analyses were made on samples taken from metavolcanic bodies of the Eastern part of the Bükk Mts. Our investigations in the frame of the CriticEl project (research for critical raw material potential) were focused on the BR. This formation is an acidic, calc-alkaline stratovolcanic complex in origin, which could be divided to two horizons according to the trace element geochemistry. The upper horizon suffered potassic metasomatism which caused significant changes in the chemistry and mineralogy as well. There are also small variations in the trace element geochemistry in samples from shear zones.

Outcrops of the BR are bordered on SW by a major fault zone, separating two structural units of different tectofacies. The strongly folded basin and platform facies limestone formations of the SW side host several metavolcanic bodies which all proved to belong to the SB horizon. In contrast with BR, SB is characterized by alkaline, basic rocks forming beds of mixed material within basin and platform facies limestone formations. Frequent repetition of volcanic beds could be attributed to folding, but differences in trace element geochemistry indicate the possible existence of two or more subsequent bed groups.

According to our results the trace element geochemistry can be used to classify the stratigraphic position of single metavolcanic bodies. Moreover, geochemical characteristics of the metavolcanics seem to be bound to structural units, which may reflect different geodynamic setting of the two major structural units in the Triassic.

High-temperature fracturing and grain-size-sensitive creep in lower crustal gabbros: Evidence for coseismic loading followed by creep during decaying stress in the lower crust?

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The mechanism of shear zone formation in lower crustal rocks at high temperatures involves brittle fracturing. Deformation of the Hasvik gabbro in northern Norway commences by fracturing. The 10–20 µm-wide fractures show little displacement. The fine-grained plagioclase and orthopyroxene in the fractures lack a crystallographic preferred orientation (CPO) or a systematic crystallographic orientation with respect to the host grains. Fracture zones grade into narrow shear zones, which are made up of fine (10–20 µm), equant grains of recrystallized plagioclase, amphibole and pyroxene. Recrystallized plagioclase, clinopyroxene and orthopyroxene have compositions different from the magmatic grains, suggesting that they have formed by nucleation and growth. Based on conventional plagioclase–amphibole thermobarometry combined with thermodynamic modelling, the shear zones have formed at temperatures and pressures of 700–750°C and 0.5–0.6 GPa. The observed primary minerals cut by fractures suggest high-temperature fracturing in the absence of high pore pressures, which implies a high strength of the lower crustal gabbros and high stresses at fracturing. The shear zones are characterized by the lack of CPO and a small grain size, suggesting that the mechanism of deformation of the fine-grained plagioclase and orthopyroxene has been grain-boundary sliding accommodated by diffusive mass transfer. The amphibole grains have strong CPOs, which most likely results from oriented growth and/or rigid-body rotations during deformation. The process that initiated the fracturing and subsequent viscous creep in the Hasvik gabbro may be resulted from a process of coseismic loading followed by creep during decaying stress in the lower crust.

The effect of rheology on the strain partitioning in the crustal section at the western margin of the Teplá-Barrandian Unit

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The interplay between rheological properties and localization of deformation was studied along the vertical crustal section exposed at the western margin of the Teplá-Barrandian Unit (TBU). This area is characterized by continuous increase in metamorphic grade from lower-greenschist to amphibolite facies rocks in mid-crustal metasediments and from amphibolite to granulite facies metabasites in the structural footwall. The present day exposure is associated with two early Variscan tectono-metamorphic stages – prograde horizontal shortening D_2 and retrograde vertical shortening event D_3.

Two principal structural patterns A and B have been recognized in the area. The simple structural pattern A is characterised by N–S trending subvertical foliation S_2, while structural pattern B exhibit almost complete transposition of subvertical fabric S_2 into gently SE to E dipping foliation S_3 forming characteristic S_2 girdle. Although the D_3 deformation is identified within pattern A, it is generally weaker and exemplified by N–S trending subhorizontal intersection lineation L_3. In pattern B, the increase of D_3 finite strain intensity is accompanied with rotation of L_3 lineation towards D_3 stretching direction plunging gently to the E.

In studied area, the two structural patterns form a sequence ABAB from structural top to structural bottom and the boundaries between domains characterised by A and B patterns correspond to 3 major attachment - detachment zones: 1) zone of partial attachment corresponding to rheological weakening in the metasediments in the vicinity of staurolite isograd, 2) a sharp detachment driven by rheological contrast between metabasites and partially molten sediments, and 3) a detachment zone between strong melt free metagabbros or amphibolites and weak migmatitic amphibolites with eclogite lenses.

The observed rotation of lineation and formation of S_2 girdle from originally subvertical N–S trending S_2 foliation have been tested by simple kinematic model and revealed that such structural pattern requires significant simple shear component combined with either a prolate symmetry of D_3 deformation tensor or an existence of pre-S_2 E–W trending vertical fabric.

We interpret the observed deformation pattern along the studied profile as a continuous transition from mechanically coupled evolution during stage D_2 affecting the entire crustal section to mechanically decoupled evolution due to strain localization and partitioning during D_3 deformation. We suggest that localization into the mechanically weak “clutch zones” is primarily caused by thermally and compositionally controlled changes of rheological properties of studied rocks. These “clutch zones” accommodated most of the non-coaxial component of D_3 finite strain that resulted in footwall exhumation of deep seated rocks of the western margin of the TBU.

Complexity of feeding systems within monogenetic volcanoes: cases from the Bohemian Paradise, Chaîne des Puys, and New Mexico

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Common models of monogenetic volcano construction, and also for many stratovolcanoes, envision the magma feeder as a dike or pipe-like conduit transporting molten rock from a reservoir to the eruptive vent producing lava flows and pyroclastic materials. Here we report the results from three continental rift systems that are host to suites of apparently monogenetic volcanic systems. These include the Eger Rift, Czech Republic that hosts the mid-Miocene Jičín volcanic field, the Limagne rift, central France home to the late Miocene to Pleistocene Chaîne des Puys volcanic field, and the Rio Grande Rift, New Mexico, USA were the Pliocene Cerro del Rio volcanic field is well exposed. In the Czech Republic, we studied Trosky and Zebín Hills combining volcanology and petrography with ground geophysics, and rock magnetic data. In France and the USA, we combined structural analysis, paleomagnetic, and anisotropy of magnetic susceptibility data to evaluate the Lemptégy Volcano, France and the Cienega Volcano, USA. At all of these sites, natural erosion or quarrying activities from medieval times to the present day has revealed windows into the roots of the volcanic system between 100 m to 2 km depths. The volcanoes range in composition from olivine basalt to olivine nephelinite and basanite (limburgite). The results from our combined studies reveal that the feeder geometries beneath these apparently simple exteriors are complex. We show that small volcanic plumbing systems actually involve numerous feeder dikes that interact and direct magma laterally and vertically beneath the cone. These observations are consistent with other studies that suggest magmas migrate laterally towards and/or away from the volcanic vent with control by pre-existing subhorizontal structures and studies that have documented lateral flow of shallow igneous bodies at a considerable horizontal distance (>20 km) from their ascent area. We propose that as magma flows upwards, feeder dikes concentrate on a central vent. The evolving vent may attract later dikes due to weaker rock properties, heat concentration, and lower pressure. As the system grows, often the vent area becomes blocked forcing magma to flow outwards or to deviate from the feeder dikes. Feeder dikes themselves may cut the flanks and cause collapse and small flank eruptions. Finally, any flank collapse changes the local stress conditions resulting in an outward flow away from the central vent complex.

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Ancient silica sinter in the northeastern part of Krowiarki, Sudetes

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This work describes the preliminary results of study about occurrences of silica sinter in the central part of Śnieżnik unit in Krowiarki Mountains (SW Lądek Zdrój, Sudetes). The study was focused on distinctive sinter architecture forms, which are direct indicators of the specific environmental conditions in which they are created.

The silica sinter creates in hot springs, which are one of a main surface manifestation of a deeper geothermal activity. As the silica-rich fluids discharge and cool below 100°C, the silica precipitates from the solution and settles in discharging vents or adjacent pools forming rocks referred to as silica sinter. The variety of textures occurring in this rocks depends on the environmental conditions such as water temperature, pH, water depth flow rate or the presence of microbes. The geothermal reservoirs may exist at depth long after hot spring discharge expires (Lynne, 2013). For this reason presence of ancient silica sinter may be an evidence of potentially exploitable geothermal reservoirs. Silica sinter textures can be used for create paleo-flow conditions maps and give opportunity to determine ancient hot up-flow zones.

Two outcrops of silica sinter have been encountered during detailed geological mapping of north-eastern part of the Krowiarki, on the south-west slopes of Siniak mountain. Their structural position is clearly discordant in relation to adjacent marbles of Stronie Formation. These rocks are located in direct vicinity of large fault zone commonly referred to as Skrzynka-Gierałtowska Kopa Fault with NW–SE trending and smaller faults crossing it with SW–NE trending (Don *et al*., 2003). The proximity of fault zones is confirmed by the presence of tectonic breccias containing folded together marbles and amphibolites of Stronie Formation.

A number of silica textures was identified as a typical for mid-temperature hot springs conditions (35–59°C) but there are also marks of high temperature conditions; some of textures has been created in deep quiet pool and some in turbulent shallowness near hot spring vents. Discussed geothermal activity may be related to the youngest volcanic rocks recognized thus far in Poland – the basanites of Lądek Zdrój area which have been dated to early Pliocene (Birkenmajer *et al*., 2002). To confirm the origin and age of discussed rock further (geochemical and dating) studies should be performed.

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Tectonics of the Carpathian Klippen Belt in the Middle Váh River Valley (western Slovakia)

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The Pieniny Klippen Belt (PKB) and neighbouring zones of the Western Carpathians represent an ancient accretionary wedge that developed during the Meso-Alpidic (Coniacian–Eocene) tectonic epoch. The Peri-Klippen Zone in western Slovakia provides a transition from the PKB s.s., built up by the Jurassic–Eocene Oravic units (Šariš, Subpieniny and Pieniny from bottom to top), to outer parts of the Central Western Carpathians (CWC) composed of Triassic to mid-Cretaceous successions of the Fatric and Hronic cover nappe systems. It attains a width of 15 km in the Middle Váh River Valley, where it is composed of the Fatric Manín, Klape and Drietoma units, as well as their post-emplacement, Gosau-type sedimentary cover. All these units are tightly folded and imbricated. The complex sedimentary and structural rock records indicate the late Turonian emplacement of the frontal Fatric nappes in a position adjacent to or above the inner Oravic elements, where they became constituents of an accretionary wedge developing in response of subduction of the South Penninic-Vahic oceanic realm that separated the CWC and the Oravic domain. Evolution of the wedge-top Gosau depressions and the trench-foredeep basins of the foreland Oravic area exhibit close mutual relationships controlled by the wedge dynamics. The peripheral trench-foredeep depozones migrated from the South Penninic-Vahic oceanic realm towards the Oravic continental fragment in an intra-Penninic position, where the synorogenic deposits were laid down with a coarsening- and thickening-upward trend before being overthrust by the propagating orogenic wedge tip. The development of wedge-top, piggyback basins (Gosau Supergroup) was ruled by the dynamics of the underlying wedge, composed of frontal elements of the Fatric and Hronic cover nappe systems. The successive transgression-regression depositional cycles and corresponding deformation stages are interpreted in terms of a dynamic accretionary wedge that maintained the critical taper only transiently. The supercritical taper states are reflected by regression, shallowing and erosion in the wedge-top area, while the trench was supplied with large amounts of clastics by various gravity-flow types. On the other hand, the collapse stages tending to subcritical wedge taper are indicated by widespread marine transgressions in the wedge-top area and a general deepening of all basins up to bathyal depths. Accordingly, evolution of the entire trench-foredeep and wedge-top basin systems was principally governed by a complex interplay between the tectonic evolution of the Carpathian orogen, local wedge dynamics and eustatic sea-level fluctuations.

Several compressional and extensional events are documented by a structural record within the wedge and related basins. The palaeostress analysis of fold and fault structures revealed only one stress system coeval with development of the accretionary wedge, which is characterized by the E–W to NW–SE oriented main compression axis operating in a pure compressional do dextral transpressional regime. Younger, Oligocene to Quaternary palaeostress fields correspond to those widely recorded in the whole Western Carpathians.

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Fabric pattern and metamorphic evolution of southwestern Moldanubian Zone (Central European Variscides)

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We consider the late-orogenic tectonometamorphic evolution in the northern flank of the Bavarian Zone (southwestern Moldanubian Zone) called as "Bavarian Phase" (e. g. Finger *et al*., 2007). The studied area is mainly occupied by ~330 to 315 Ma granites associated with strongly deformed and anatectic rocks (e.g. Kalt *et al*., 2000). Owing to the strong late Variscan heat flow, the Bavarian Zone is clearly distinct from most other metamorphic and magmatic rocks of the Moldanubian Zone dated at ~355 to 335 Ma (e.g. Schulmann *et al*., 2009). The rocks of the Bavarian Zone were heated up and deformed at a time when most other parts of the Variscan Bohemian Massif experienced post-collisional cooling. Therefore, studied rocks uniquely reveal the younger ~330 to 310 Ma HT/LP overprint of regional pre-335 Ma structures. These late-Variscan fabrics are represented by heterogeneously developed, moderately to steeply ~NE to NNE dipping amphibolite facies foliation and compositional banding, well-developed gently ~NNW(NW) or ~ESE(SE) plunging lineation predominantly also bearing evidences of right-lateral shearing. In addition, new thermodynamic and geochronological data from metamorphic rocks and syntectonic granites suggest that the main stage of these late-Variscan high-temperature processes took place in relativelly short time-span around 325 Ma at depths around ~17 km. The intensity of "Bavarian" overprint continuously increases towards the ~SW as a result of oblique ~NW–SE right-lateral transpression. Based on our new petrological and structural data we also test a possible hypotheses of geodynamic causes of "Bavarian Phase" and increased heat flux during the later stages of Variscan orogeny.

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Anisotropy of man-made rupture strength

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At this time modelling, (not only PC modelling) is inseparable part of scientific work. It is evident that joints and faults surfaces should be anisotropic but only few papers are focused on this feature. As study of real ruptures seems to be complicated, we solve to study strength of simple man-made ruptures imitating complex geometry of real joints or faults.

We prepare simple type of man-made surface geometry of rupture. Surface shape of it was chosen uncomplicated with parallel ridges and mirror symmetry (Figure A). At first, one very precise mould was made, after that sixteen wax casts of one side of ideal rupture was produce (i.e. eight two-sided ruptures). These first-generation casts were used for casting of one big final silicone mould. This big mould enabled to cast many series of identical gypsum model with uniform surfaces. We made ten series (80 completely ruptures) for the moment to testify the chosen method.

Ideal models were tested in 5 different directions. Striation on model surface was selected as a "zero" direction. Thanks to mirror symmetry of surfaces it was not necessary to tests all 16 directions as on real non-symmetrical ruptures (Proisl, 2013). Tests were made only in 5 directions in range 0°–90° and results were copied in other directions (see grey numbers Figure B). Gypsum models were tested at shear tensile machine Matest A129. Shear strength was obtained under fixed normal stress component equal to 9.95 kPa. Resultant shear strengths were plotted on spider diagrams.

We can observe the lowest values of shear strength in direction parallel to striation. This result was expected and correlated with real ruptures. But distribution of shear strength along model rupture shows one peak of shear strength maximum, which is in oblique angle 67.5° This result confirm results of testing of real ruptures (Proisl, 2013). Other data were lower than this oblique one, even in direction perpendicular to striation. This result of testing indicates some unknown strength behaviour of striated planes.

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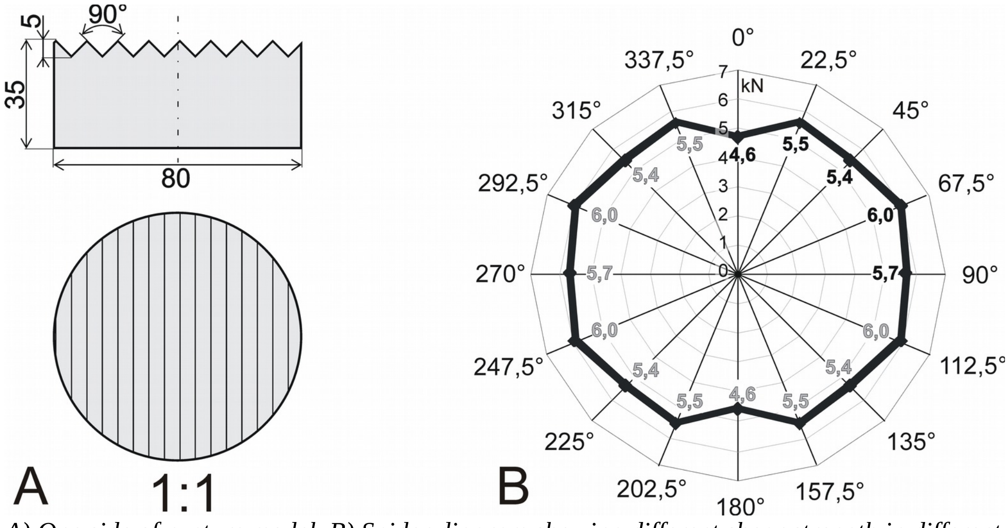

A) One side of rupture model. B) Spider diagram showing different shear strength in different direction of the rupture model.

P–T conditions of crustal xenoliths and gravity measurements: architecture and composition of the crust in an accretionary orogen, Mongolia

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Mongolia is located in the southern part of the Central Asian Orogenic Belt, which is a typical accretionary orogen divided into several lithotectonic domains. These domains are defined by contrasting lithostratigraphical, geochronological and structural features and are juxtaposed along steep strike-slip faults. From the north to the south of southern Mongolia, the domains were defined as follow: the Baydrag, the Lake Zone, the Gobi-Altai Zone, the Trans-Altai Zone and the South Gobi Zone. Many tectonic scenarios were proposed to explain the relationship between these different domains but a coherent geodynamic model remains under debate. Available granulite xenoliths in the Cenozoic and the Quaternary volcanic rocks in the Tariat and Dariganga regions enabled us to identify the composition of different crustal levels by using thermodynamic modelling. The calc-alkaline crustal xenoliths in their alkaline magma host are cumulates of underplated basalts in a subduction tectonic context. The performed pseudosections indicate that the maximum pressure for Tariat and Dariganga xenoliths are respectively 11.2 and 8.1 kbar at 850°. These MP-HT rocks represent therefore the middle to lower crust at the Cenozoic period. They vary from felsic to intermediate compositions respectively for Tariat and Dariganga regions, depending on the type and on the sampled level of the crust. Xenoliths give information on the composition of the crust at different depth levels at a local scale, whereas geophysical investigation can provide the architecture of the crust at a regional scale. To the south of Altai city, up to 160 km long gravity profiles were acquired during the 2013–2014 geophysical surveys. These surveys cross the Lake Zone, the Gobi-Altai Zone and the Trans-Altai Zone. The profiles are oriented N–S and NE–SW and these directions are perpendicular to the main geological units. The raw gravity measurements will be processed applying the usual corrections like the tide correction, the drift of the gravimeter, the elevation and latitude corrections, to get the free air anomalies; following with the topography and the terrain corrections to obtain the Bouguer anomalies along these profiles. The aim of this gravity survey is to provide new insight of the architecture of the crust in southwestern Mongolia, especially at the middle and lower crustal levels.

Metasomatic interaction of cm-scale mantle xenoliths with felsic granulite (St. Leonhard granulite massif, Lower Austria)

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Spatially limited zone of uncommon melange of felsic to intermediate granulite mixed with small (0.X to X cm) particles of mafic to ultra-mafic rocks can be observed in St. Leonhard granulite massif in Lower Austria. Such an assemblage of lithologies allows observation of spectacular reaction textures and study of diffusion-related processes that appear at their borders on micro-scale. The mafic xenolits can be divided into two main groups according their primary mineral assemblage; interaction of each of them with the felsic host lithology produces different reaction corona: 1) Grt-pyroxenite / eclogite composed of Grt (X_{Fe} = 0.29; Alm_{24}; Py_{59}; Sps_1; Grs_{17}) and Cpx (X_{Fe} = 0.13; Jd_6; $CaTs_{10}$) is surrounded by ~2 mm thick layer of Opx+Plg symplectite. Both phases show zoning with increase of X_{Fe} (Opx; 0.25→0.27) and Ab (Plg; 56→63%) towards the felsic granulite. Inside of the pyroxenite, Grt is partially replaced by Amp+Plg symplectite, Cpx contains Opx lamellae and is sometimes replaced by Amp at its rims. Grt grains are often located across the border of the pyroxenite and symplectite, which may imply that the symplectite layer was formed on the expanse of the pyroxenite rather than to growth from its surface towards the felsic matrix. Such Grt shows strong XFe modification from 0.29 in the xenolith to 0.52 at the contact with the Qtz-rich matrix, while Grs (15–17%) and Sps (1–2%) contents remain almost unchanged. At the contact with the felsic granulite, Grt often has a zone rich in Plg inclusions. In some cases, Bt appears in the the symplectite or inside of the xenolith. Pyroxenite xenoliths are surrounded by ~2 mm wide zone depleted in Kfs, pointing to intensive diffusion of K from the granulite to the mafic xenoliths, which may be connected with growth of Amp and Bt in the coronas or inside of the xenoliths. 2) Rare peridotite xenoliths composed of Ol (X_{Fe} = 0.12) are surrounded by a layer composed of Opx grains with pronounced zoning defined by X_{Fe} increase (0.12→0.27) from Ol to the granulite matrix, sometimes accompanied by Phl. In case of Ol-xenoliths, no Kfs depleted zone in the granulite is developed. In addition, single Grt grains with high Mg and Ca content in core (X_{Fe} = 0.29; Grs_{17}) are present in the matrix. They have rim enriched in Fe and depleted in Ca (X_{Fe} = 0.50; Grs_8) with numerous inclusions and embayments of Plg. They can contain inclusions of Cpx rich in Jd (10%) and CaTs (17%) and were presumably separated form the pyroxenites.The felsic granulite itself has generally well equilibrated mineral assemblage consisting of Grt, Kfs, Plg, Qtz, and Opx±Bt. In places, clusters of small Grt grains with Sp inclusions and surrounded by Plg can be observed, indicating that Ky was involved in the earlier mineral assemblage. Equilibration of the mineral assemblage defining the host granulite was estimated by pseudosection modelling to ~850–950°C and 11–13 kbar, which are also supposed P–T conditions of the formation of the reaction textures around the xenoliths. Interesting fact is that conditions of Ky stability for such composition are very limited and restricted to lower T, which is in contradiction with the observed Grt+Sp pseudomorphs after Ky. Possible explanation is that the lithology surrounding the mafic xenoliths represents originally typical felsic Ky+Kfs+Grt+Qtz granulite that was modified by diffusion of Fe+Mg during the interaction with the mafic lithologies and the Ky destabilization (and Opx formation) is a result of changing rock composition rather than P–T conditions. With help of P-X pseudosection modeling, it was estimated that decreasing of Fe and Mg by ~20 % already leads to breakdown of Opx and formation of Ky at P–T conditions of interest.

Structural and metamorphic record in schist mantle of the Saxonian Granulite Massif

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The Saxonian Granulite Massif in the Saxothuringian Domain of the Bohemian Massif, is represented by a single granulite body consisting of felsic and mafic granulites formed during Variscan tectono-metamorphic event. The granulites with peak metamorphic P–T conditions of ~2.3 GPa and 970–1060°C (Fuhrman & Lindsley, 1988; Rötzler & Romer, 2001) were rapidly exhumed and emplaced into the palaeozic sedimentary cover sequence, which resulted into contact metamorphism affecting these metasedimentary rocks and development of a contact metamorphic aureole. In the map view, the granulite body has elongated shape with the long axis oriented in NE–SW direction and it is surrounded by the so called schist mantle reflecting the extent of the contact metamorphic aureole. Within two kilometers distance away from the contact with granulite body, the metamorphic grade in metasediments decreases from cordierite gneiss, andalusite bearing micaschist to phyllite.

Detailed field structural analysis in the studied area revealed a deformation record associated with four main deformation phases. In granulites the oldest deformation fabric is steep NE–SW trending and contains kyanite and sillimanite. This fabric is locally overprinted by the subhorizontal green schist facies fabric, mainly along the margins of the granulite body. In metasediments, the original sedimentary layering can be locally identified. In the vicinity of the contact with the granulite body, the metasediments show subvertical fabric, which contains or is overgrown by the contact metamorphic minerals. This originally NE–SW trending fabric is isoclinally folded and overprinted by the subhorizontal axial-planar green schist facies foliation. The subhorizontal NE–SW fold axes rotated or became stretched in the form of sheath folds to NW–SE orientation parallel to stretching lineation. All fabrics mainly in metasediments are subsequently affected by two episodes of post-metamorphic folding. The first one is more pronounced and results into development of meter- to kilometer-scale open folds with subvertical NE–SW trending axial planes and subhorizontal axes. The later folding is less important and it is associated with formation of kink bands with NW–SE trending axial planes and subhorizontal axes.

Our preliminary PT results suggest that the granulite body was rapidly exhumed and emplaced into shallow crustal levels. The contact metamorphic aureole in the surrounding metasediments developed in association with steep deformation fabric, which was later affected by subvertical shortening.

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Volcanic and seismic hazards in Southern Ethiopia

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The Czech Geological Survey (CGS), Geological Survey of Ethiopia (GSE), Aquatest and Institute of Rock Structure and Mechanics of the Czech Academy of Sciences carried out in 2012–2014 cooperation project focused on geological hazards in Southern Ethiopia, which was supported by the Czech Government through the Czech Development Agency. The area of interest was delimited between latitude 6° and 8° North and longitude 37.5° and 39° East situated mainly in the central part of the NNE–SSW to NE–SW trending Main Ethiopian Rift (e.g. Bonini *et al.*, 2005). The Main Ethiopian Rift recorded a typical evolution of continental rifting, from fault-dominated rift morphology in the early stages of the continental extension toward magma-dominated extension during break-up due to extension between the Nubian and Somalian plates from Miocene to Quaternary (e.g. Agostini *et al*., 2011). The dominant rift-related faults are mostly parallel to the MER dipping steeply to ~ESE or WNW. These faults are associated with ~E or W steeply plunging slickensides and normal kinematic indicators. Subordinate faults dip steeply to moderately to ~N (NNE) or S (SSW) with evidences for both normal movement and right-lateral oblique movement. The large composite silicic volcanoes alternate with volcanic fields of mafic monogenetic cones. Most of recent silicic volcanoes occupy former mid-Pleistocene (1.3–1 Ma) Calderas. The two post-caldera volcanoes within the Corbetti caldera emerged after the 200 ka ignimbrite-forming eruption. The last explosive pumice eruption dated by ^{14}C to ca. 400 BC was followed by four effusive eruptions of obsidian lavas. We also documented shift from comenditic towards pantelleritic trend of Corbetti rhyolitic melts during the Holocene. The basaltic scoria- and tuff-cones and maars are generally arranged parallel to N–S trending fault zones. Most of the fields show negligible magmatic differentiation except of relatively small North Chamo Volcanic Field where complete differentiation trend from basalt towards tephriphonolite was documented. In some cases, significantly zoned magma chamber was observed even within evolution of a single scoria cone. From a geological perspective this area gives unique evidences of recent tectonic and volcanic activities with direct linkages to the Geohazard risks.

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Variscan tectonics of the Southern Drahany Upland

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The Drahany Upland reveals an insight into the structural development of a flexural foreland basin at the western edge of the Brunovistulian lithospheric block of the Bohemian Massif during the Variscan orogeny. In the Early Carboniferous this region is characterized by synorogenic sedimentation coeval with nappe stacking (e.g. Bábek *et al.*, 2006). The source region of the sediments experienced rapid exhumation processes from deep crustal levels to the surface as evidenced by abundant HP-rock pebbles in debris flow deposits of the Viséan Myslejovice formation (maximum burial min. 12 kbar, ~44 km depth at 339±0.7 Ma; mid-crustal overprint in ~22 km depth at 333 Ma; age of conglomerate sedimentation 326±2 Ma, Kotková *et al.*, 2007). These constraints have been classically interpreted as the result of south-easterly directed emplacement of high grade "Moldanubian" nappes thereby feeding the evolving flexural foreland basin (Hartley & Otava, 2001 and references therein). Such an accretionary wedge scenario predicts intense pre- and post-diagenetic deformation of the synorogenic clastics during ongoing convergence at least in the proximal parts of the basin.

Our field observations are as follows: Despite the rare occurrence of small scale slump structures a characteristic feature of the synorogenic sediments is the essential absence of tectonically induced soft-sediment deformation. Moreover, huge areas of the Carboniferous "Culm" succession are hardly affected by post-diagenetic deformation. Localized narrow shear zones reactivating primary anisotropies like slumping horizons, gentle E to SE vergent folding and younger reverse faults are the typical structures. In contrast the underlying Devonian carbonate successions exhibit voluminous ductile shear zones. The preferred orientation of the stretching lineation is NNE–SSW with shearing top to the NNE, i.e. the typical feature of the nappes of the Moravosilesian Zone (e.g. Schulmann & Geyer, 2000). We interpret this twofold architecture of the Drahany Upland with the decoupling of the synorogenic basin above a decollement zone from the underlying strongly deformed Devonian successions during ongoing NNE directed convergence. Despite the emplacement of the Protivanov nappe, which we interpret as an out of sequence thrust, the synorogenic basin itself was not affected by pervasive nappe stacking. The very weak thermal overprint in the southern Drahany Upland (Franců *et al.*, 2002) corroborates this interpretation and questions the accretionary wedge model. Alternatively, we present an oblique ramp model. Oblique convergence may form a central transpressive zone with the dominance of strike-slip movements and a pro-wedge thrusting zone, both active at the same time. Rapid exhumation coupled with uplift and erosion occurred in the central zone, the rock debris deposited in the adjacent basins of the thrusting zone.

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Evolution of depositional systems in the Blatné depression of Danube basin: Trakovice 1 and Trakovice 4 well case study

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Trakovice 1 and 4 wells, drilled in the Blatné depression of the northern Danube Basin penetrated the sedimentary record in total thickness of 1510 to 1600 m. Most of the drilled interval is ranked into the Langhian (Lower Badenian) and Serravallian (Upper Badenian - Sarmatian) stage. We document the: NN4, NN5 and NN6 calcareous nannoplankton Zones; as well as the CPN7 and CPN8 foraminifer Zones (N 9, 10, 11 of global foraminiferal zonation; MMi4a; MMi5 and MMi6 of Mediterranean foraminiferal zonation). Sedimentation began during the transtensional opening of the depocentre and basal conglomerates formed by local fan-deltas quickly enter the forming depression (early Langhian). During the late Langhian sedimentation changed to shelfall and gradually passed into deltaic. The provenance analysis confirmed prominent erosion in the delta catchment area which was also accompanied by volcanism. Due to active extension, the deltaic system soon retreated and the area was flooded in the weary end of the Langhian stage. Shelfall environments occurred again. The early Serravallian is typically transgressive with deeper shelfall conditions passing gradually to coastal plains in the late Serravalian. These environments are later replaced by shallow lake and alluvial plain conditions during the Tortonian – Pliocene (Pannonian – Pliocene) interval.

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Geology of the Eastern Alps – summary and open questions

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Today it is widely accepted that the Alpine orogen in central Europe developed from two oceanic and two continental domains. In the course of the breakup of Pangea a southern continent assemblage including Africa (including the "Adriatic spur"), Australia and Antarctica drifted eastward with respect to Laurasia, causing the opening of the Atlantic with an eastward extent represented by the Penninic Ocean. From the East the Neotethys Ocean extended into the Alpine realm. Crustal fragments incorporated in the Eastern Alps, which have derived from the northern and southern continental realms show differences with respect to their pre-Alpine magmatic inventory. On the one hand in the Laurasia-derived Subpenninic Superunit Variscan orthogneisses with a similar age spectrum to the Moldanubian Superunit occur, whereas on the other hand the Adria-derived Austroalpine and Southalpine superunits are characterised mainly by Ordovician and Permian magmatic rocks. The differences in the magmatic inventory indicate a certain distance in space after the Variscan tectonometamorphic cycle and prior to the opening of the Mesozoic oceans.

Shortening processes preluding the Alpine collisional event start in the Middle Jurassic and lead to the obduction of ophiolite nappes from the Neotethys oceanic realm onto the continental margin of the "Adriatic spur", which was in a lower plate position during this process. With respect to the Eastern Alps this situation chanced in the Early Cretaceous, because during initial stages of the Alpine collisional event the northernmost part of the former "Adriatic spur" (including the major part of the recent Austroalpine nappes) was subducted below the main part of the Adriatic Plate (including the uppermost Austroalpine nappes and the Southalpine Superunit). This switch from a lower plate to an upper plate position of the Adriatic plate in the area of the Eastern Alps has been recently explained by a Late Jurassic tear-fault with a sinistral offset cutting through the Adriatic Plate (Böhm *et al.*, 2013). According to Stüwe & Schuster (2010) this subduction zone is active until recent times with continental and oceanic lithosphere coming in at different times. During this processes the Alpine orogen consisting of a pro-wedge including the Austroalpine, Penninic, Helvetiv (Ultrahelvetic), Subpenninic and Allochthone Molasse/Waschberg nappes and a retro-wedge consisting of Southalpine nappes developed (Schmid *et al.*, 2004).

Oligocene slab break of caused magmatic activity along the Periadriatic Fault System, forming the boundary between the pro- and retro wedge. According to Handy *et al.* (2014) a flip in subduction polarity has occurred below the eastern part of the Eastern Alps since that time. The main argument for this interpretation is a "gap" in the tomographic anomalies below South Tyrol and a northward dip of the anomaly in the eastern part. However, dip angle and depth of these anomalies are varying in different tomographic models (Mitterbauer *et al.*, 2011). An alternative explanation for the steeply northward dipping slab beneath the eastern parts of the Eastern Alps might be the dragging of an originally southward dipping European slab due to its retreat into the Carpathian embayment (Carminati *et al.*, 2012). The correlation of units from the Eastern Alps and Western Carpathians is challenging. While minor problems occur within Penninic derived units, equivalents of Austroalpine units in the Inner Western Carpathians are hard to determine (Froitzheim *et al.*, 2008). Often identical lithostratigraphic units appear in different tectonic positions and it is highly important to distinguish between lithostratigraphic and tectonic similarities.

New airborne geophysical maps of the E-part of the Krušné hory Mts.

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The Teplice rhyolite (Mlčoch & Skácelová, 2010) is a striking radioactive body comparable in its radioactive effect with the Moldanubian durbachite intrusions (for example Knížecí Stolec or Třebíč pluton). From radioactive point of view the Teplice rhyolite can be divided to three N–S belts different in the K, U and Th ratios:

- the W part rich in thorium and uranium with medium contents of potassium, matching to porphyric rhyolite ignimbrite with biotite and/or altered pyroxene
- the “central” part rich in potassium but less increased in uranium and thorium, corresponding with rhyolite to trachyte pyroxene ignimbrite
- the E part showing common concentrations of the natural radioactive elements mostly produced by felsitic leucocratic rhyolite.

Another remarkable radioactive anomaly belt is produced by the Loučná-Fláje granite porphyry dyke. The most striking part of the dyke belongs to its middle segment in the vicinity of the Loučná hill. Only slightly increased concentrations of K, U and Th accompany the Fáje pluton. It corresponds to common granite–granodiorite plutonite bodies. The crystalline complexes surrounding the magmatic bodies show ordinary contents of radioactive elements. The lowest concentrations of radioactive elements belong to local outcrops of basic neovolcanites and also to the large “Děčín Cretaceous Area”. The magnetic pattern of the W part of the Teplice rhyolite without porphyry dykes is completely free of magnetic anomalies, however, its E part with frequent porphyry dykes shows several small-extent and low-amplitude magnetic anomalies. Similar small-extent and low-amplitude anomalies were found within the surrounding crystalline complexes. They probably disclose buried dykes of granite porhyry. In addition to the elongated but not continuously developed magnetic response of the N–S trending Loučná-Fláje granite porphyry dyke, there were two similar, NW–SE trending subparallel elongated anomalies found. They apparently pertain to subsurface dykes unknown up to now.

Distinct magnetic anomalies, mostly circle-shaped and chimney-type, are caused by basic neovolcanites. These volcanites penetrate through the Teplice rhyolite, the Fláje pluton as well as the surrounding complexes of metamorphites and Cretaceous sediments of the “Děčín Cretaceous Area”. Besides the outcropping bodies, these anomalies also disclose completely buried volcanics or they can indicate real and mostly much larger subsurface volcanic bodies appearing only as very small oucrops. Large extent magnetic anomaly zone was found in the “Děčín Cretaceous Area”. It pertain to the Ordovician phylite sequences of the Labe zone (Elbeshiefergebirge) laying bellow several hundred metres thick Cretaceous sediments (details in Zabadal *et al*., 2014).

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Deformation sequence of the Izera metamorphic complex close to the Intra-Sudetic Fault Zone (West Sudetes, Poland)

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The Intra-Sudetic fault zone is one of the major, Variscan age dislocation in the Sudetes. This NW–SE trending fault is geological boundary between different geological units. Near the Pilchowice (West Sudetes) the dislocation separated two metamorphic complexes: Kaczawa complex on NE segment and the and Izera complex on SW. In the research area the Izera block is built by various gneisses and amphibolites. Structural study, based on geological mapping and microstructural analyses of samples of the gneisses, showed few deformations stages. The oldest stage (D_1) occurred in the epidote–amphibolite facies. In this stage the penetrative S_1 foliation and L_1 lineation in the Izera gneisess were formed. The microstructural image shows asymmetric, σ-type feldspar porphyroclasts of the sinistral sense of shear (top to NW), which are typical for D_1 deformation. The second stage (D_2) was under conditions of the greenschist to epidote–amphibolite metamorphic facies. Ductile dextral shear zone were formed and is marked by pressure shadows of the σ-type feldspar porphyroclast and "bookshelf structures". Close to the fault surface, meso-scale drag folds were formed. These deformation documented the main, strike-slip displacement of the Intra-Sudetic fault zone. During the third phase (D_3) the Izera gneisses were folded to south vergented meso-scale folds. Recognized kink-folds and the cataclastic fracture of the gneisses correspond to the last, semi-brittle stage deformation (D_4) in the Izera metamorphic complex, as well as to the reverse movement (sinistral) of the ISF. On the base of the data from the regional literature (Mazur, 1995; Aleksandrowski *et al*., 1997; Mazur & Aleksandrowski, 2002), D_1 phase occurred during late Devonian–early Carboniferous time. D_2 and D_3 events were in early Carboniferous–late Visean. D_4 deformation occurred at the turn of late Carboniferous–early Permian periods.

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Lower Palaeozoic tectonometamorphic evolution of the Bij formation, Hovd Zone, western Mongolia

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The accretion formation of the Central Asian Orogenic Belt (CAOB) is broadly accepted (Sengör *et al*., 1993), but accurate time constrains of the amalgamation of individual terranes are still scarce. The Hovd Zone forms NNW–SSE trending elongated belt, situated between the Lake Zone arc system on the NE and the Altai backarc/forearc basin domain on the SW and has been interpreted as an accretionary wedge (Badarch *et al*., 2002). The central part of Hovd Zone is built by the Bij formation of uncertain age and the Lower Palaeozoic flysch sequences. The Bij formation predominantly contains various types of strongly deformed, greenschist–amphibolite facies metamorphosed magmatic and volcanic rocks locally intercalated by metapelites and marbles.

Three successive deformational fabrics occur in metamorphic rocks of the Bij formation. The earliest S_1 fabric is locally preserved as relicts of isoclinal folds within younger S_2 foliation. The S_1 fabric was largely obliterated by the younger D_2 deformation, which led to the development of the predominantly mylonitic S_2 fabric. The S_2 fabric is reworked by D_3 folding and thrusting, which is connected with ~NE–SW dextral transpression. The chemical U–Th–Pb method on monazite (Montel *et al*., 1996) has been used to date tectonic and thermal processes affecting the rocks of the Bij Formation. The results of monazite U–Th–Pb dating of five samples give three group of ages: 1) Early Silurian ~440 Ma (436±5 Ma; 440±8 Ma; 439±12 Ma) ages on monazites from the matrix, 2) Middle Devonian ~390 Ma (388±9 Ma; 389±18 Ma; 394±21 Ma) ages on monazites associated with S_2 fabric and Late Devonian (358± 9 Ma) age from the preserved monazite cores, 3) Early Carboniferous ~330 Ma (331±10 Ma; 333±10 Ma) ages from the recrystallized marginal parts of monazites and from the monazites grown synchronous with the development of the S_3 cleavage. The two older groups of ages perfectly fit the isochron line (Suzuki & Adachi, 1991) whereas the youngest ages are statistically more scattered. Partial rejuvenation (Pb loos) of the youngest monazites triggered by hydrothermal alterations is possible. The field observation combined with monazite ages implies that the Bij Formation underwent polyphase tectonometamorphic evolution during Lower Palaeozoic. We interpret this domain to represent allochtonous sliver which was buried to upper/middle crust levels and then exhumed within the accretionary wedge (Hovd Zone) during tectonical amalgamation of the Altai terrane to the Lake Zone in the Silurian–Devonian times. Finally, this domain was affected by NE–SW Early Carboniferous convergence, leading to considerable shortening of the Hovd Zone.

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Comparison of thrusting in two distinct orogens

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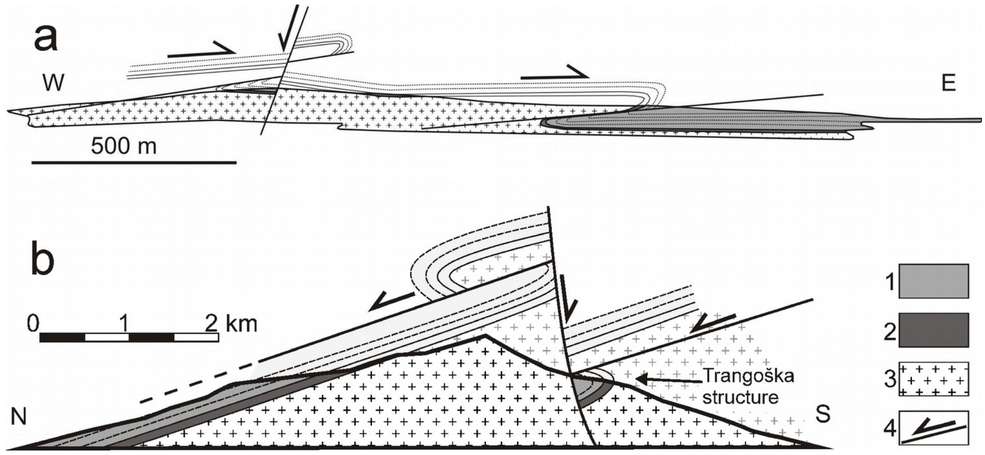
This comparison demonstrates the features of thrust tectonics of crystalline units and its autochthonous sedimentary covers in Variscan and Alpine Orogeny. The tectonic contact zone of Brno Massif with Devonian sediments of Moravian Karst was compared to the contact of Tatric crystalline unit with its Mesozoic sedimentary series in Low Tatras.

In his early years, Radim Kettner was studying tectonics in the Carpathians, mainly in Low Tatras, and thus later in his life when mapping the Bohemian Massif he started noticing the same features of thrust tectonics. This kind of features have been further observed in the latest years, as we have been conducting more thorough research based on field mapping and structural analysis in northern part of Moravian Karst (Bohemian Massif) and Trangoška structure in Low Tatras (Carpathians). This study demonstrates similarities of these two orogens.

The most noticeable feature in studied areas, is that both of the crystalline units with their sedimentary sequences, which consist of basal clastics covered by carbonates, have been deformed and these sedimentary sequences have been preserved in the form of stripes in between the crystalline units. This phenomenon has been caused by the main deformational phase, where thrusting took place. In this thrusting phase, rocks of the crystalline units have overthrusted their formerly autochthonous sedimentary cover sequences and duplicated the composition. The thrusts causing this duplicity are represented by mylonite zones in the crystalline rocks as well as in the sedimentary sequences. Thrust planes have very shallow angles and are mostly parallel to bedding of sedimentary cover. Moreover during the thrusting, along with the thrust planes the bedding in sedimentary rocks has been overturned and formed almost isoclinal folds with the vergence of the thrusts (Figure).

Both tectonic zones were transformed to contemporary form and position by later deformation phases. These later deformations made the overall geometry of structures more complicated and thus more challenging to solve, but the similarities between these two areas suggest, that the incorporation of former forelands into orogeny used more or less the same mechanism in the Variscan and in Alpine orogeny.



Schematic cross-sections across northern part of Moravian Karst (a) and central part of Low Tatras (b). 1 – Carbonates; 2 – Basal clastics; 3 – Crystalline basement; 4 – Thrusts and faults.

Segmented normal fault geometries interpreted in the "Dogger quarry", Gerecse Hills, Hungary

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Upper crustal faults cannot be considered as an isolated structure, they mostly consists of several segments, as in strike as dip direction. The geometry, linkage and distribution of the segments depend on the lithology, the development stage, and the scale of view. On the poster I present a case study from north Hungary, where such segmentation can be interpreted. The outcrop of the "Dogger quarry" is located south from Lábatlan village in the Gerecse Hills, which is a part of the northern Transdanubian Range of Hungary. The outcrop reveals marine sequences, which in the Early to Middle Jurassic. The extensional regime is part of the well-known Early Jurassic deformation, which occurred between the Neotethys Ocean and the incipient Alpine Tethys (Ligurian – Piemont Ocean). Three formations are visible in the outcrop, two competent limestone formations (the older Pisznice, and the younger Tölgyhát Formation) separated by one well traced marl unit, with relatively less competent rheology (the Early Toarcian Kisgerecse Formation). The Jurassic sequences have deformed by numerous fault segments, which have a complex geometry as result of several deformational phases. Extensional structures dominate, such as normal faults, drag folds, rotated blocks and extended (boudinaged) layers. The size of the outcrop doesn't allow measuring all structures from the floor, so to collect fault-slip data was necessary to use alpine technics. To give a better interpretation of fault geometries I used Agisoft PhotoScan photogrammetric program, which makes a 3D spatial data from single photos. However, to provide a realistic interpretation for structural development cannot be constructed ignoring fault segmentation models (Childs *et al.*, 1996; Peacock, 2001). The most striking fault step in the outcrop is located on the western side of the mine. This segmentation is associated with the most significant displacement and it is interpreted as vertically (along-dip) segmented normal fault segments. The original two segments have extensional overstep geometry (Peacock & Zhang, 1994), with a middle connecting segment having formed later. The displaced formation boundaries demonstrate normal dip slip separation, but the middle segment shows reverse slip. This geometry could be explained by several displacement episodes. We suggest that the original dip of the middle connecting segment was not a reverse fault but overturned to be reverse. Originally it could have been a steeply dipping segment with normal kinematics. This rotation of the connecting segment was absorbed by the less competent marl unit with ductile deformation. Therefore "flow" of the marl unit and the locally altered stress resulted in the tilting of the middle connecting segment. This study emphasize that apparent contractional structures could be the result of extensional faulting interacting with fault-related folding.

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3D modelling of the Variscan granites in the Erzgebirge-Vogtland-Fichtelgebirge area

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The late- to post-Variscan (325–295 Ma) peraluminous, transitional I-S granites of the Erzgebirge (Krušné hory) – Vogtland – Fichtelgebirge (Smrčiny) are subdivided into five different groups based on compositional and mineralogical properties (Förster *et al*., 1999): (i) low-F biotite granites; (ii) low-F two-mica granites; (iii) high-F, high-P_2O_5 Li-mica granites; (iv) high-F, low-P_2O_5 Li-mica granites and (v) medium-F, low-P_2O_5 biotite granites. These granitic rocks were emplaced during three late- to post Variscan intrusion events: low-F granites were emplaced between 325–320 Ma; high-F, high-P_2O_5 Li-mica granites at 317–310 Ma; high-F, low-P_2O_5 Li-mica granites and medium-F, low-P_2O_5 biotite granites are younger than 310 Ma (e.g. Romer & Thomas, 2005). Although these granites show different geochemical compositions and intrusion ages, previous models only consider the petrographic discrimination of granite and country rock (the so called "granite surface") thereby negating the existence of different granitic bodies (Tischendorf *et al*., 1965).

We present a 3D model of the different granite complexes that are constrained by gravimetric and airborne magnetic data (Geological Survey of Saxony, LfULG), reflection seismic profiles (DEKORP) and 2658 wells (377 wells drilled into granitic rocks). The granitic plutons can be explained by five complexes: (i) NNE trending, low-F two-mica granite massif (Bergen-Lauter-Schwarzenberg); (ii) two NNW trending, low-F biotite granite massifs (Nieder-bobritzsch-Fláje, Kirchberg-Aue-Beierfeld-Nejdek-Karlovy Vary); (iii) an ENE trending, high-F, low-P_2O_5 Li-mica granite massif (Hora Svaté Kateřiny-Seiffen-Schellerhau-Altenberg-Markersbach); (iv) an E trending, high-F, high-P_2O_5 Li-mica granite massif (Eibenstock-Nejdek-Geyer-Ehrenfriedersdorf-Satzung-Pobershau); (v) an E trending, medium-F biotite granite massif (Schönbrunn-Eichigt-Gottesberg). As a geometric consequence, the high-F, high-P_2O_5 Li-mica granites form a large, E trending plutonic complex that underlies, and hence, melted older granitic bodies (e.g. the low-F granite plutons of the Aue-Schwarzenberg zone within the Gera-Jáchymov Lineament). We interpret the Fichtelgebirge granites as the western continuation of the Erzgebirge granites that were displaced along a latest Variscan NNW striking dextral fault. Probably in the Cenozoic, the Mariánské Lázně Fault reactivated this Variscan mechanical anisotropy. According to reflection seismic profiles, most of the granites terminates in a depth of 5–10 km suggesting a laccolithic structure. This contradicts the classical view of a giant, deep seated Erzgebirge-Vogtland batholith (Tischendorf *et al*., 1965).

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Linking zircon ages to P−T paths through textural position and REE patterns: The eclogite-mafic granulite to intermediate granulite transition from the Blanský les, Bohemian Massif

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The eclogite-mafic granulite occurs as a rare boudin within a felsic kyanite-K-feldspar granulite in a low strain zone. Its boundary is marked by important metasomatism involving diffusional gain of potassium on a centimeter-scale, and probable infiltration of felsic melt on a larger scale, converting the eclogite-mafic granulite into intermediate ternary feldspar-bearing granulite. The peak P−T conditions of the eclogite based on inclusions in garnet are 18 kbar at an uncertain temperature, with matrix reequilibrated at 12 kbar and 950°C. Four samples representing the transition from the eclogite-mafic granulite to the intermediate granulite were studied. In the eclogite, REE patterns in the garnet core show no Eu anomaly, compatible with crystallization in the absence of plagioclase and consistent with the inferred initial eclogite-facies conditions. Towards the rim of garnet LREE decrease and a weak negative Eu anomaly indicates passing into HP granulite-facies conditions with plagioclase present. The outermost rims of garnet next to ternary feldspar in the intermediate granulite show the lowest LREE and deepest Eu anomaly.

Zircon was analyzed by LASS (laser-ablation split-stream inductively coupled plasma-mass spectrometry) and shows U-Pb dates from 404 to 334 Ma. There is a trend of flattening of the slope of HREE from the old to the young dates with an apparent discontinuity, not clearly related to a discontinuity in the ages. The Eu anomaly is mostly negative, but some zircon in the eclogite has no Eu anomaly. The oldest dates are interpreted as crystallization of the protolith at > 404 Ma without garnet and with plagioclase, therefore as a shallow level mafic rock, likely a gabbro. The flat HREE patterns and negative Eu anomaly or its absence indicate (re)crystallization in presence of garnet, with or without plagioclase. A correlation between decreasing Yb/Gd with age indicates that the spread of dates is likely to be mainly a result of incomplete recrystallization of the protolith zircon along the P−T path, thus making interpretation of the dates difficult. However, some textures indicate crystallization of new zircon that may be linked to the P−T path. A zircon included in garnet and crystallized with omphacite gives ca. 350 Ma that is interpreted as the minimum age of the eclogite facies metamorphism. A zircon grown partially along grain boundaries within the recrystallized opx-cpx-gar-plg matrix gives 338 Ma, interpreted as the age of exhumation to 12 kbar. Older dates and zircons with steep HREE patterns are clearly more abundant in the eclogite-mafic granulite, and dates older than ca. 345 Ma and/or showing steep HREE patterns are very rare in the intermediate granulite. This points to the metasomatic processes that converted eclogite-mafic granulite to intermediate granulite facilitating zircon recrystallization.

Intermediate granulite produced by transformation of eclogite at a felsic granulite contact in Blanský les, Bohemian Massif

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Layers or bodies of intermediate granulite on scales from a cm to a hundred metres occur commonly within the felsic granulite massifs of the Bohemian Massif. Their origin is enigmatic in that they commonly have complex microstructures that are difficult to interpret, and therefore even the sequence of crystallization of minerals is uncertain. At Kleť, in the Blanský les massif there is a revealing outcrop in a low strain zone in which it is clear that intermediate granulite can form by the interaction of felsic granulite with eclogite. The eclogite retains garnet from its eclogite heritage, the grains at least partially isolated from the matrix by a plagioclase corona. The original omphacite-dominated matrix of the eclogite now consists of recrystallised diopsidic clinopyroxene, orthopyroxene and plagioclase, with minor brown amphibole and quartz. The modification of the eclogite is dominated by addition of just K_2O and H_2O, rather than all the elements that would be involved if the process was one of pervasive melt infiltration. This suggests that the main process involved is diffusion, with the source being the felsic granulite, or local partial melt of the granulite. The diffusion occurred at about 950°C and 12 kbar, with the main observed effects being 1) the un-isolation and preferential destruction of the interior part of some of the garnet grains by large idiomorphic ternary feldspar, 2) textural modification of the matrix primarily involving the recrystallisation of clinopyroxene into large poikiloblasts containing inclusions of ternary plagioclase, and 3) conversion of low-K plagioclase in the matrix into ternary feldspar by incorporation of the diffused-in K_2O. The phase equilibria in the intermediate granulite are consistent with the chemical potential relationships that would be superimposed on the original eclogite by the felsic granulite at 950°C and 12 kbar.

Fracturation mechanisms on Mokrsko Deposit

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Locality Mokrsko-west is located inside the Josef mining gallery and belongs to the ore district Psí Hory Mountains, known for its high content of micro-granular gold. It is situated within the apophysis of Sázava tonalite, which is a part of Central Bohemian Plutonic Complex, located southerly from Prague. Besides other structural elements which were studied and measured, the whole locality contains the network of sheeted quartz veinlets which was the main aim of research. Data from vectorization, image analysis of photographic documentation of the gallery adits and electron microscopy have been used. The statistical approach has been used to quantify proportions of mineral phases within the quartz veinlets, their cumulative spacing and fractal distribution. Image analysis confirmed the presence of K-feldspathic metasomatism which affects the plagioclase grains. It forms rims on the edges of the quartz veinlets. The proportional relationship of K-feldspar and quartz within the veinlets wasn't confirmed. It's therefore possible that they were two separate processes of the uncertain time relation. Transfer from the lognormal distribution in histograms of vein spacing in drill-cores to the more normal distribution of the veinlets in the gallery walls was observed. Results from the cumulative spacing analysis confirmed this trend. This implies the relative homogeneity of the system and even spacing of the quartz veinlets. Fractal dimensions calculated from the dataset of 8 000 separate measurements gives the D > 0.9. This as well corresponds with the even spacing distribution. It is likely that such a distribution of veinlets is not result of simple extensional jointing and hydrothermal fluid infill. Possible explanation might be that the channelized fluid flow propagated upwards within the previously altered and therefore weakened rock. The origin of the sheeted vein system spreading all along the Mokrsko-west gallery could belong to the continuous fluid flow during one regional stress regime.

Grain-scale pressure variations in metamorphic rocks: implications for the interpretation of petrographic observations

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Recent work on mineral reactions and microstructures in metamorphic rocks has focused on forward modelling of phase equilibria and on their description through chemical potential relationships which control mass transfer in rocks. The available thermodynamic databases and computer programs for phase equilibria modelling have significantly improved the quantification and understanding of geodynamic processes. Therefore, our current methodological framework seems to be satisfactory. However, the quantification approaches in petrology focus on chemical processes with oversimplified mechanics. A review of the recent literature shows that mechanical effects in rocks may result in the development of pressure variations even on a hand specimen or grain scale. Such variations are critical for interpreting microstructural and mineral composition observations in rocks. Mechanical effects may influence element transport and mineral assemblage in rocks. Considering the interplay of mechanical properties and metamorphic reactions is therefore crucial for a correct interpretation of microstructural observations in metamorphic rocks as well as for quantification of processes. In this contribution, the implications of the new quantification approach for phase equilibria modeling as well as diffusion modeling will be outlined. The impact of ignoring grain-scale pressure variations on geodynamic modeling and our understanding of the processes in the Earth's interior will be assessed.

Late- to post-Variscan thermal evolution of the Mid-German Crystalline Rise and Rotliegend in Thuringia (central Germany) by means of fission-track and U-Pb LA-ICP-MS dating on zircon and apatite

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The region around Suhl and Zella-Mehlis (Thuringia, central Germany) is positioned at the intersection of the NE–SW trending Mid-German Crystalline Rise as part of the European Variscan orogen and the NW–SE trending Franconian Fault System. It is characterized by large exposures of presumably Carboniferous granitic basement surrounded by a post-Variscan Rotliegend succession comprised of both clastic and magmatic rocks. Between Permian and Late Cretaceous times it underwent a polyphase late- to post-Variscan thermal evolution in conjunction with repeated contractional and extensional phases of deformation. As a result of this, basement crystalline rocks crop out in the Thuringian Forest to the north of the Franconian Fault System, while they are buried by a more than 2 km thick succession of Rotliegend and Triassic sediments in the southerly adjacent foreland.

To get a better understanding of the thermal history of the area, fifteen samples from Carboniferous and Permian granitic basement as well as Permian clastic and volcanic rocks were taken. Apatite and zircon fission track ages of these samples were analyzed. In order to not only be able to model the cooling ages but also a cooling path over time, the length distribution of the fission tracks was analyzed, that is thought to correlate with the cooling of the samples through their corresponding annealing temperature window. This window is at about 60–110±10°C for apatite (Green & Duddy, 1989) and 180–300°C for zircon (Bernet, 2009). Additional data is provided by measurements of zircon and apatite U-Pb ages, using the LA-ICP-MS (laser ablation inductively coupled plasma mass spectrometry). In combination of these methods, the history of the samples can be modelled over time, from their formation to uplift, renewed burial and final exposure as seen today.

Preliminary data shows Middle to Late Jurassic cooling of the samples of the Mid-German Crystalline Rise beneath the zircon annealing window. Apatites show Late Cretaceous cooling ages, which progressively decrease to the south-west of the considered area. The track-length distributions in apatites reveal a subset of distinctively shortened fission-tracks that suggest a polyphase thermal evolution.

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Using of lidar-derived digital elevation model in geological mapping: examples from Magura Unit, Polish Outer Carpathians

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The aim of the research was to analysis utility of using airborne Light Detection and Ranging (LIDAR) products for geological analysis, particularly for identification the tectonic structures in the mountains area. Presented examples come from Magura Unit, the southern part of the Polish Outer Carpathian fold and thrust belt. Between 2010 and 2013 airborne laser scanning data were acquired. Point cloud that was collected allowed to built High Resolution Digital Elevation Model with resolution of 1 meter ground sampling distance. The HR-DEM was analyzed by the slope, aspect and roughness maps. The maps used algorithms that are available in GRASS GIS and QGIS tools.

Results of this research showed that the correlation between rock competence and surface roughness can be identify with high precision. However, effects of this methods depends on difference of rocks lithological heterogeneity. In the area of high diversity of rocks complex competence we can identify on DEM-based maps lines that corresponds to rock layers. Together with morphology it allows to define strike/dip value using classical intersection methods. In the HR-DEM we can observe also lineaments, that can be identify as faults. In some situation we can even define the strike-slip component. Fieldwork research confirm compatibility between DEM interpretation and measurement of structures. Obtained results shows that HR-DEM can be successfully used for geological mapping and to interpret the structural style in the Outer Carpathian region.

Paleozoic evolution of Kock Fault Zone: Lublin Basin (central–east Poland)

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The Kock Fault Zone (KFZ) is a distinct structural element of c.a. 160 km in length, located in the marginal SW part of the EEC within the Lublin Basin. The KFZ separates the Lublin Synclinorium, to the SW, from the Hrubieszów Elevation, to the NE. Although this structure has drawn attention of several generations of geologists, there is still a lack of genetically and kinematically consistent concept of its evolution. Our research has ambitions to fill this gap, at least partially, by integrated interpretation of a large number of seismic profiles with the archive core samples. A present geometry of the KFZ is a product of the multistage evolution of the earlier Kock Fault and the later Kock Thrust phases.

The first documented stage of the Kock Fault activity is linked with the late Caledonian deformation phase, during which it had a normal fault kinematics visible in the thickness changes of the Late Silurian deposits, resembling roll-over anticline. In the central part of the KFZ, the maximum thickness contrast of the Silurian deposits across the Kock Fault indicates displacement in a range of 2000 m. This extensional phase is related to the formation of the Caledonian foredeep in which the foreland extension was governed by both a slab-pull and plate bending mechanisms.

In Late Famennian, the Kock Fault underwent inversion probably in transpressional stress regime that result in erosion of more than 2000 m of Devonian and partly Silurian deposits at the Hrubieszów Elevation. In the beginning of Carboniferous, the major basaltic intrusion stage is noted along the KFZ. It is expected that a deeply rooted source of magma was activated in the extensional (or trantensional) stress regime. From above, we infer that the so called Bretonnian tectonic phase evolved from initial compressive to the final extensional character. During Carboniferous stage of the Lublin Basin subsidence the Kock Fault was probably not active.

The initial stage of the Late Carboniferous (Westphalian) contraction of the Kock Fault might begin from a deep-rooted compression that led to subsequent minor inversion. Further evolution of the distant Variscan collision zone turned the compression character into a thin-skinned that resulted in development of the Kock Thrust. The location and orientation of this thrust is controlled by the Kock Fault scarp across which mechanically weak Silurian deposits of the Lublin Synclinorium contact with much stronger Cambrian rocks of the Hrubieszów Elevation, playing a role of buttress. The Kock Thrust broke the pre-existing steeply-dipping Kock Fault and shifted a part of it north-eastwards, causing also minor folding of the shallow sedimentary cover of the Hrubieszow Elevation. Balancing of the cross sections indicates the maximum thin-skinned thrust fault displacement in a range exceeding 3 km.

Later phases of minor deformation of the KFZ start from the transpression, probably in the final stage of the Variscan collision. It was followed by relaxation and extension of fracture network combined with hydrocarbon migration. In the Mesozoic times minor selective reactivation either in a manner of buckling folding (Triassic) or in a style of normal faulting (end of Cretaceous) is possible to distinguish at seismic lines.

Magnetic fabrics as markers of emplacement strain in shallow magma chambers and lava domes, Štiavnica volcano-plutonic complex, Western Carpathians

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The Miocene Štiavnica volcano–plutonic complex, Western Carpathians, is an erosional relic of a large stratovolcano with collapse caldera (Lexa *et al*., 1999). Significant vertical relief allows studying different structural levels of the stratovolcano from lava flows and domes to sub-volcanic plutons. The anisotropy of magnetic susceptibility (AMS) was used to quantify the magnetic fabrics and parameters of two sub-volcanic plutons (diorite and granodiorite; ~13.3 Ma) and three selected andesite lava flows/domes (referred to as Domes 1–3) extruded along the caldera ring fault (~13.1–12.8 Ma, data from Chernyschev *et al*., 2013). A total of 1184 specimens from 88 stations were collected using portable hand-held gasoline drill. The high susceptibilities (10^{-2} to 10^{-3} SI) and thermomagnetic experiments on representative specimens indicate nearly pure magnetite as a dominant carrier of magnetic susceptibility in both plutonic and volcanic rocks. Presence of primary magnetite microphenocrysts is typical for all andesite samples. However, most of the andesites contain also secondary magnetite in opacitized rims of hornblende±biotite phenocrysts or pseudomorphs. Different amounts of opacitization are ascribed to variable syneruptive oxidation. As no tectonic overprint in magmatic or solid state was identified, we interpret the magnetic fabrics as shape or distribution anisotropy of magnetite, recording increment(s) of magma emplacement strain. The AMS analysis revealed significantly different construction mechanisms of the sub-volcanic chambers. The diorite is interpreted as a discordant NW–SE elongated stock with steep fabric, whereas the granodiorite was constructed as a tabular, bell-jar pluton. The latter displays complex fabric pattern, consistent with a two “layer” structure emplaced in two stages via piecemeal pluton floor subsidence. First, a thin sill intruded along a major subhorizontal basement/cover detachment. Second, the pressurized magma arrested at the detachment zone and pushed the fractured pluton floor down to subside into a deeper magma reservoir. This process opened space for new arriving magma which flowed along multiple subsiding fault-bounded blocks. Magnetic fabrics of lava flows/domes exhibit two contrasting patterns. (1) Domes 1 and 2 indicate SE-trending (towards the caldera interior) simple central flow zone, oblique to the ring fault which spreads laterally at the sides. To the contrary, the Dome 3 shows more complex fabrics with at least two N–S-trending feeder zones, parallel to the straight segment of the ring fault. We suggest that such flow patterns may record different caldera collapse mechanism: trap-door caldera (Domes 1 and 2) and piecemeal caldera (Dome 3). Moreover, it is inferred that different styles of collapse of the caldera floor could have potentially involved simultaneousy, or that more than one collapse episode with different mechanisms occurred over a short time period.

Lexa, J., Štohl, J. & Konečný, V., 1999. The Banská Štiavnica ore district: relationship between metallogenetic processes and the geological evolution of a stratovolcano. *Mineralium Deposita*, **34**, 639–654.

Chernyshev, I.V., Konečný, V., Lexa, J., Kovalenker, V.A., Jeleň, S., Lebedev, V.A. & Goltsman, Y.V., 2013. K-Ar and Rb-Sr geochronology and evolution of the Štiavnica Stratovolcano (Central Slovakia). *Geologica Carpathica*, **64**, 327–351.

Mineral chemistry of Pt_3–C_1? metabasite intercalations and marble lenses within the Stronie Fm. from W flank of the Orlica-Śnieżnik Dome

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In the western limb of the Orlica-Śnieżnik Dome, the Sudetes, in the metasedimentary Stronie Formation, metabasalts (Floyd *et al*., 2000; Ilnicki *et al*., 2013) are found adjacent to ~500 Ma metarhyolites and the contact zone is decorated by some tens of cm thick marble lenses while large marble bodies occur nearby. Such assemblage, set in mica schists, was observed in a small quarry 2 km ESE of the village of Gniewoszów. Metabasites, of which some are pillow-shaped, occur as laminated, massive, greenish dark grey rocks, whereas metarhyolites are massive or banded. Both lithological types alternate and display transitional boundaries. The metabasite-metafelsic transition zones (BFTZ) developed to form kind of few cm wide Amp-rich and Qz-rich bands as a mixture of two-source volcanic material. A detailed analysis of Amp, Pl, Ep, Chl and Opq of the metabasites and BFTZ was performed. Marble lenses within the metabasites are composed of Cal, Qz and Ab with Act inclusions. 5–20 cm wide transition zones (MATZ) between such lenses and the amphibolites contain significantly different Amp and Pl than the host amphibolites and several Chl+Amp and Amp-Pl-Cal bands. High (> 0.5) XMg of analyzed amphiboles together with variable Si^{4+} and Al_{tot}, indicate Mg-Act, Tr, Mg-Hbl, Ts and rarely Fe-Ts. Act and Tr (XMg: 0.7–0.93; Si^{4+} > 7.5 pfu) most often concentrate as inclusions in Ab of the marble lenses or associate with calcite prisms in the BFTZ, whereas Mg-hornblende is widespread and became most frequent amphibole of the metabasites. Tschermakite (Si^{4+}: 5.7–6.2 apfu, XMg: 0.55–0.7, CaB: 1.8–1.9 apfu, Al^{IV}–$[Na+K]^{A}$ > 1.5) and Fe-Ts (Si^{4+}: 0.55–0.7 pfu, XMg < 0.55, Fe_{tot}: 1.9–2.3 pfu, $Al^{IV}+Fe^{3+}+Ti+Cr$ > 1.7) occur as coarse euhedral blasts in paragenesis with Mg-Chl scheridanite (Si: 5.3–5.6 pfu, $Fe^{2+}+Fe^{3+}$: 1.5–1.8 pfu, XMg: 0.81–0.84 pfu), especially in the BFTZ. In the studied rocks, Ca and Na-enriched rims were found in the coarse euhedral Ts blasts, particularly abundant in the MATZ, having composition of barroisite and winchite (Na^{M4} > 0.6 pfu, Al^{IV}–$[Na+K]^{A}$: 0.3–0.6; calc. 23(O)) with increased glaucophane end-member. Sheridanite is a background for those amphiboles. Plagioclases do not exceed 30% An. Ab often forms poorly oriented poikiloblasts, whereas oligoclase (17–29% An) greatly contributes to the foliated fabric in the amphibolites. This may be interpreted as increased temperature during formation of the main amphibole foliation. Zoned Ep presents moderate (25–40%) decreasing ps ratios toward the rims. Fe-oxides (Ilm, Mag) most frequently assemble with Fe-Ts, oligoclase and high-ps Ep of MATZ. The observed amphibole zonation, coupled with decreasing ps ratios of Ep, and increasing An content in oligoclase, suggests progressive type of metamorphism with increased pressure during the final stage of amphibole recrystallization. Because of the extremely opposite P–T conditions for stable scheridanite and hi-Al Fe-Ts with sodic rims and their relation, not simultaneous growth of these minerals and diaftoritic Mg-chlorite recrystallization might be concluded.

Floyd P.A., Winchester J.A., Seston R., Kryza R. & Crowley Q.G., 2000: Review of geochemical variation in Lower Palaeozoic metabasites from the NE Bohemian Massif: intracratonic rifting and plume-ridge interaction. In: Franke, W., Haack, V., Oncken, O., Tanner, D. (Eds.), Orogenic Processes: Quantification and Modelling in the Variscan Belt, 179, pp. 155–174.

Ilnicki S., Szczepański J. & Pin C., 2013. From back-arc to rifted margin: Geochemical and Nd isotopic records in Neoproterozoic?-Cambrian metabasites of the Bystrzyckie and Orlickie Mountains (Sudetes, SW Poland). *Gondwana Research*, **23**, 1104–1121.

Accessory REE-Th-U minerals: a key to unravel Alpine fluid-driven alterations in granitic orthogneisses (the Veporic Unit, Western Carpathians)

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A variety of decompositions of REE-Th-U-bearing accessory minerals were identified in Paleozoic granitic orthogneisses from the pre-Alpine basement in the Veporic Unit, Central Western Carpathians (Slovakia). The Ordovician granitic rocks were subjected to Variscan amphibolite facies metamorphic-anatectic overprint. Chemical, electron-microprobe U-Th-Pb dating of primary monazite and xenotime reveals their magmatic Middle Ordovician age (monazite: 471±4 to 468±6 Ma, xenotime: 472±13 Ma) and/or a metamorphic-anatectic Variscan (Carboniferous, Visean) age (monazite: 345±3 Ma).

The younger, most likely post-Variscan (Permian?) and Alpine (Cretaceous) fluid-rock interaction events caused a local breakdown of primary magmatic and/or metamorphic-anatectic monazite-(Ce), fluorapatite, xenotime-(Y) and allanite-(Ce). Monazite-(Ce) breakdown produced secondary egg-shaped coronal structures (100 to 500 μm in diameter) with concentric newly-formed minerals. Two principal monazite breakdown stages and newly formed mineral assemblages are recognizable: (1) partial to complete replacement of primary monazite with an internal fluorapatite to hydroxylapatite + $ThSiO_4$ phase (huttonite or thorite) zone and an external allanite-(Ce) to clinozoisite zone; (2) hydroxylbastnäsite-(Ce) partly replacing apatite + $ThSiO_4$ and allanite to clinozoisite aggregates. Moreover, recrystallization of fluorapatite and monazite in some places resulted to very fine-grained mixture of REE-Fe-Th-Ca-P-Si phase of non-stoichiometric composition. Rarely secondary sulphatian monazite-(Ce) II was formed along tiny fissure fillings (up to 10 μm thick) in fluorapatite I. The secondary monazite II is rich in calcium (up to 5 wt. % CaO, 0.20 apfu Ca) and sulphur (2.8 to 5.4 wt. % SO_3, 0.08 to 0.15 apfu S). Partial dissolution-reprecipitation of xenotime-(Y) produced numerous tiny uraninite inclusions which are irregularly distributed in altered parts of xenotime. These altered areas of xenotime are distributed along grain boundaries or in irregular zones. The chemical dating of the uraninite inclusions in xenotime is problematic mainly due to their very small size, providing rejuvenated age population (161 to 284 Ma), which indicates an evidence of younger (Permian to Cretaceous) event responsible for nucleation of uraninite inclusions within the altered xenotime crystals. In addition, primary allanite-(Ce) was decomposed to secondary REE carbonate minerals, located in fissures and cracks of altered allanite crystals: compositions between the bastnäsite and synchysite end-members: bastnäsite-(Ce) to hydroxylbastnäsite-(Ce), and synchysite-(Ce) to its unapproved hydroxyl-dominant member [“hydroxylsynchysite-(Ce)”]. The fluid-driven hydrothermal-metamorphic overprint and partial breakdown of primary monazite, xenotime, apatite and allanite was initiated by fluid sources differing in composition. Stage (1) originated due to post-magmatic/metamorphic hydrothermal fluids, whereas stage (2) indicates an input of younger, carbon-bearing metamorphic-hydrothermal fluids and precipitation of the REE carbonate minerals. The first stage might be related to post-magmatic fluids released from Permian acidic volcanic and micrograntic vein swarms croscutting orthogneisses. The second stage is consistent with the composition of inferred metamorphic fluids that acted in the Veporic basement and cover rocks during Late Cretaceous post-collision extension.

The role of preexisting fractures and their reactivation potential on the design of a hot dry rock geothermal reservoir in the Mid-German Crystalline Rise (central Germany)

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The Mid-German Crystalline Rise (MGCR) in Thuringia (central Germany) is part of the European Variscan orogen and hosts large extents of Visean granites (ca. 350 Ma), locally overlain by up to 3 km of Early Permian to Mid-Triassic volcanic and sedimentary rocks. A geothermal gradient of locally up to 36°C km^{-1} suggests that such subsurface granites form an economically viable hot dry rock reservoir at > 4 km depth. In order to assess the likelihood of reactivating any preexisting fractures during hydraulic reservoir stimulation, slip and dilation tendency analyses (Morris *et al*., 1996) were carried out. For this purpose, we determined orientations of preexisting fractures in 14 granite exposures along the southern border fault of an MGCR basement high. Additionally, the strike of 192 Permian magmatic dikes affecting the granite was considered. This analysis revealed a prevalence of NW–SE striking fractures (mainly joints, extension veins, dikes and subordinately brittle faults) with a maximum at 030/70 (dip azimuth/dip).

Borehole data and earthquake focal mechanisms reveal a maximum horizontal stress SH_{max} trending N140°E and a strike-slip regime. The effective in-situ stress magnitudes at 4.5 km depth were estimated at 230 and 110 MPa for SH_{max} and Sh_{min}, respectively, assuming hydrostatic pore fluid conditions and a friction coefficient of 0.85 on preexisting fractures. In this stress field, fractures with the prevailing orientations show a high tendency of becoming reactivated as dextral strike-slip faults if stimulated hydraulically. To ensure that a stimulation well creates fluid connectivity on a reservoir volume as large as possible rather than dissipating fluids along existing fractures, it should follow a trajectory at the highest possible angle to the orientation of prevailing fractures, i.e. subhorizontal and NE–SW oriented.

Morris, A., Ferrill, D. A. & Henderson, D. B., 1996. Slip-tendency analysis and fault reactivation, *Geology*, **24**, 275–278.

Sarmatian to Quaternary evolution of palaeostress field in the northeastern part of Danube Basin (Slovakia)

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The Danube Basin, located among the Eastern Alps, Western Carpathians, and Transdanubian Mountains, covers northwestern part of the Pannonian basin system. This basin is represented by typical morphostructures on contact with Western Carpathian Mountains with finger-like character. Based on this basin/mountain relationships the area is traditionally divided into four subbasins (Blatné, Rišňovce, Komjatice, and Želiezovce depressions). From the geological point of view, the Danube Basin is filled by the middle Miocene to Quaternary marine, lacustrine to alluvial sedimentary sequences. The pre-Cenozoic basement of this basin is composed of the Tatric and Veporic units, except southernmost part formed by the tectonic unit of the Transdanubian Mountains. This study integrates faults-slip analysis and palaeostress reconstruction to discuss palaeostress field evolution since Sarmatian. Structural analysis was carried out by inverse and P–T axes methods. The structural measurements were realized in outcrops with the following lithostratigraphy: (1) Lower Badenian shallow sea to deltaic Príbelce Member; (2) deltaic to alluvial Lower Badenian sediments of the Baďany Formation; (3) Upper Miocene alluvial sequence of the Volkovce Formation; (4) Upper Pliocene to Lower Pleistocene river sediments of the Lukáčovce Member; (5) Pleistocene loessial sequences. Based on the obtained fault-slip data and palaeostress reconstruction, four palaeostress phases can be distinguished: (1) the oldest Upper Badenian to Lower Sarmatian phase is characterized by strike-slip tectonic regime with the general orientation of compressional stress axis (σ_1) in the N–S direction and perpendicular tension (σ_3); (2) Sarmatian to Lower Pannonian strike-slip tectonic regime is defined by the NE–SW oriented σ1 and the NW–SE oriented σ_3; (3) the Pannonian to earliest Pliocene phase can be described by extensional tectonic regime with the orientation of σ_3 in NW–SE direction; (4) the youngest recorded extensional tectonic regime is characterized by the NE–SW to E–W orientation of the σ_3 axis. This tectonic phase can be tenuously dated at Pliocene to Quaternary age and is most probably still active.

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New constraints on the Cretaceous–Quaternary tectonic and thermal evolution of the Tatra Mts. (Western Carpathians): depicted from structural, sedimentary, geomorphological, and fission track data

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The Tatra Mts. and their surroundings are located in the northern portion of the Central Western Carpathians along the state border of Slovakia and Poland. Tectonic and thermal evolution of the Tatra Mts. area was revealed by multiple geochronological and geological methods, such as structural and sedimentary analysis, tectonic geomorphology, and zircon and apatite fission track dating method. Based on the newly obtained data (Králiková *et al*., 2014), the study area underwent complex Alpine tectonic evolution, which can be divided into several tectonic stages (TS). The first tectonic stage (TS-1; ~95–80 Ma) can be dated back to mid-Cretaceous nappe stacking when the Tatric Unit was overlain by Mesozoic sequences of the Fatric and Hronic nappes, which occurred during the Eo-Alpine phase. The fully annealed zircon samples suggest that the metamorphic temperature was in excess of ~320°C. The principal compressional stage of the Alpine orogene was replaced by the Late Cretaceous to Palaeogene orogene collapse followed by an orogen-parallel extension. At this time the Tatric crystalline basement was exhumed (and cooled), indicated by 70 to 60 Ma old zircon fission track ages. Extensional tectonics was replaced by transpression to transtension during the Late Palaeocene to Eocene (TS-2; ~80–45 Ma). The Late Eocene to earliest Miocene can be characterized by formation of the Central Carpathian Palaeogene Basin which kept the underlying Tatric crystalline basement in the temperature range of approximately 120–200°C (TS-3; ~45–20 Ma). The final cooling of the Tatra massif was a consequence of an asymmetric neotectonic exhumation that could be linked with the sub-Tatra faulting in the southern edge of the massif during the Miocene (TS-4; ~20–7 Ma). Slow middle-late Miocene exhumation rate of the Tatric crystalline basement was revealed by apatite fission track data of 9–12 Ma. Additionally, the late Miocene evolution was characterized by formation of the basic Western Carpathian planation surface – intramountain level. The final appearance of the mountains range in morphology above the surrounding foreland has been linked to accelerated tectonic activity since the Pliocene (TS-5; ~7–0 Ma).

Králiková, S., Vojtko, R., Sliva, Ľ., Minár, J., Fügenschuh, B., Kováč, M. & Hók, J., 2014. Cretaceous–Quaternary tectonic evolution of the Tatra Mts (Western Carpathians): constraints from structural, sedimentary, geomorphological, and fission track data. *Geol. Carpath.*, **65**, 307–326.

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P–T evolution of high pressure micaschists and gneisses from Erzgebirge Mountains (Bohemian Massif)

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Erzgebirge Mountains form part of Saxothuringian domain of the European Variscides and they are exposed at the western margin of the Bohemian Massif. In the studied area three distinct units have been previously defined: para-autochtonous basement; and Lower and Upper Crystalline nappes (Konopásek et al., 2001). Both nappes are formed by metasediments, orthogneisses with associated eclogite bodies, but reveal different P-T conditions. The Upper Crystalline Nappe show extensive partial melting and high-temperature deformation with peak metamorphic established at ca. 740-845°C at14-16 Kbar. In contrast, the Lower Crystalline Nappe shows lower T around 500-550°C. In this study we focus on the high pressure micaschist and gneisses from the Upper Crystalline Nappe and we aim to decipher their P-T-t path as well as timing of the extensive migmatization at high pressures. To achieve these aims we will combine careful petrographic observations with thermodynamic modelling and Lu-Hf geochronology on garnets together with U-Pb monazite dating.

Konopásek, J., Schulmann, K. & Lexa, O., 2001. Structural evolution of the central part of the Krusne´ Hory (Erzgebirge) Mountains in the Czech Republic—evidence for changing stress regime during Variscan compression. *Journal of Structural Geology*, 23, 1373–1392.

Thermal structure of Orava-Nowy Targ Basin (Western Carpathians): results of vitrinite/huminite studies

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The Orava-Nowy Targ Basin (ONT) is filled by Neogene non-marine sequence up to 1300 m thick and composed largely of claystones and siltstones. The ONT Neogene sequence overlies: (1) the intramontane Podhale Flysch Basin (Inner Carpathians), (2) Pieniny Klippen Belt and, (3) the Magura Nappe (Outer Carpathians). For determination of the organic thermal maturity in this region, the vitrinite/huminite reflectance studies of lignite and dispersed organic matter in siliciclastic strata were carried out on 41 surface samples collected from the ONT Neogene sequence (16 samples of claystones and mudstones, 8 samples of lignites), 5 samples of Oligocene claystones from the Podhale Flysch Basin and 14 samples of Paleocene-Miocene claystones from the Magura Nappe.

The existence of more than one vitrinite/huminite population points to detrital contamination and precludes calculation of mean reflectance value (Ro) for some of the studied samples. Therefore, on multimodal histograms, the lowest reflecting population corresponding to the first modal value was chosen for calculation of the reflectance (R1) and paleotemperatures.

For the ONT Neogene sequence, the histograms of all lignite samples show unimodal distributions of vitrinite/huminite reflectance values, whereas, most histograms of claystone/mudstone samples are multimodal. Moreover, all lignite samples contain measurable vitrinite/huminite, whilst, in claystones sampled in the upper part of the ONT sequence the reflectance measurements were not possible due to lack of vitrinite/huminite particles. Most of the lignite samples contain very low-reflecting vitrinite/huminite (mostly <0.2 %Ro). Only in two lignite samples, collected at the bottom of the ONT sequence, the Ro amounts to about 0.35%. On reflectance histograms of the claystone samples, up to three population of vitrinite/huminite were observed. The R1 values vary between 0.14 and 0.53%. Other populations shows mean reflectance values of about 0.40% and from 0.65 to 1.% respectively. The highest values of R1 (0.43%-0.53%) are observed for claystone samples collected at the bottom of the ONT sequence. The reflectance histograms for the Podhale Flysch Basin and the Magura Nappe samples show both unimodal and bimodal distributions of values. For the Podhale Flysch Basin, and Magura Nappe samples, the R1 values vary between 0.25 and 0.57%, and 0.47% and 1.1% respectively. Most of the Magura Nappe samples show the R1 values between 0.6 and 0.7%.

Multimodal reflectance histograms show that redeposition of the vitrinite/huminite is very common in the ONT Neogene strata. The detrital vitrinite showing the highest reflectance is probably derived from the Magura Nappe. In the ONT Neogene sequence, the highest R1 values indicate paleotemperatures from 46°C to 73°C. These temperatures were calculated for samples collected in the lowest part of the Neogene sequence which underwent long-term effective heating during burial. The samples collected in the upper part of the sequence show very low degree of maturation of the vitrinite/huminite particles. This is probably due to burial which was not deep enough for the adequate maturity of organic matter.

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Tectonometamorphic evolution of the Rehamna massif (Morocco, Variscan belt)

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The Morocco Variscan belt is considered to be the south-western continuation of the European Carboniferous orogen on the NW Gondwana margin. The Rehamna Massif, a paleozoic massif located on the Meseta domain which is part of this belt, is affected by three main deformation events (D_1, D_2 and D_3) of variable intensity and geometry, associated with a Barrovian metamorphism. The first forms a flat-lying metamorphic foliation S_1, which is deformed by WSW–ENE trending F_2 folds with associated sub-vertical S_2 cleavage, then heterogeneously reworked by NNE–SSW trending F_3 folds with an S_3 cleavage moderately to steeply dipping to ESE. Each deformation lead to the development of a new foliation and the crystallisation-deformation relationships show that biotite, chlorite, garnet, chloritoid and staurolite grew in the S_1 fabric, and that chloritoid and staurolite continued their growth in the S_2 and S_3 fabrics. Two types of andalusite porpyroblasts located around granitic intrusions were identified: some are clearly post-tectonic whereas others are presumably coming from an early event. This study combines crystallisation-deformation relationships, in addition to the results of mineral chemistry and mineral zoning, with pseudosection modelling and geochronological datas. Based on the resulting P–T–d paths, three main tectonic events have been recognized: 1) Southward thrusting of an Ordovician sequence over the Proterozoic basement, its Cambrian sedimentary cover and the overlying Devono-Carboniferous basin. This event caused subhorizontal shearing and prograde Barrovian metamorphism of the buried rocks. 2) Continuous shortening resulting first in continuation of burial, then in the development of a syn-convergent extrusion of metamorphosed units to form a dome elongated E–W. This was responsible for syn-convergent detachment of the Ordovician upper crustal sequence. 3) The next episode of convergence took place in a ESE–WNW direction orthogonal to the previous one and is characterized by the accretion of the Rehamna dome to the continental basement in the west. Existing Ar/Ar dating shows that the first and the second deformations occurred during the Late Carboniferous to Early Permian (315–290 Ma) and that the third deformation took place during the Early Permian (290–275 Ma). Geochronology with in situ U/Pb dating on monazites is performed in order to date the individual phases of metamorphism and constrain the timing of the deformations events.

Deformation enhanced melt migration of extruding orogenic lower crust: an example from the Eger Crystalline Unit

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The Eger crystalline unit (ECU) represents a rapidly (1.1–2.5 mm/year) exhumed lower felsic crust that extruded along the Teplá-Barrandian – Saxothuringian suture zone at ~340 Ma. The ECU consists of high-grade gneisses and migmatites, granites, granulites and metasediments. Peak metamorphic conditions were established at ca. 740–845°C and 14–16 kbar.

Detailed structural analysis of the ECU revealed four deformation events related to lower crustal flow and subsequent exhumation of the entire unit to middle crustal levels. The deformation record was studied along the profile following the Eger (Ohře) river. The oldest subhorizontally lying S_1 fabric is defined by monomineralic banding in migmatitic banded orthogneisses. This fabric is overprinted by sub-vertical, east-west trending axial planes and axial-planar cleavage S_2 with subhorizontal axes and typically shows strong deformation gradients, locally forming mylonitic migmatites. These S_2 fabric related deformation gradients are associated with distinct lineation of variable plunge. Thus while in the S_2 low strain domains the lineation resulted from S_2/S_1 intersection and is subhorizontal, in the S_2 high strain domains the lineation reflects stretching and is subvertical. S_2 fabrics in the western part of the area are overprinted by open folds with NW–SE trending vertical axial planes (S_3) and subvertical axes. In the eastern part of the area, brittle-ductile kink bands with shallowly dipping axial planes affect the sub-vertical S_2 fabric. Locally, the S_2 fabric was exploited by pervasive porous waves of granitic melt that progressively transformed the banded orthogneiss to migmatitic gneiss and migmatites. Petrological observations suggest that such pervasive flow and emplacement of the granite sheets took place at relatively high pressures (>15–20 kbar at~800–850°C). Extensive melting of the gneiss was likely triggered by water/fluid influx.

The Trans-European Suture Zone in Variscan times: a granite perspective

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The Trans-European Suture Zone (TESZ) is a NW-trending transcurrent feature understood as a transition between the East European Platform (Baltica) and the West European Platform. It is concealed under Permo-Mesozoic and Cenozoic deposits, thus mainly imaged by seismic data and rather poorly constrained by geological observations. The structure of TESZ is hence debated. One of the interpretations assumes that it may have stemmed from a ~200 km wide margin of Baltica (Bayer *et al.*, 2002) which was attenuated during rifting and break-up of Rodinia. The SW edge of the Baltica margin coincides with the Elbe Line (Bayer *et al.*, 2002), Dolsk Fault Zone and Kraków-Lubliniec Fault Zone (Malinowski *et al.*, 2005). In Poland, 300 Ma granitoids intruded into these fault zones, being spatially associated or just capped by Lower Permian rhyolites and ignimbrites. Structurally, these rocks appeared in a far foreland of the Variscan orogen in central Europe. Timely, they followed crustal thickening of the foreland at 340–307 Ma (Żelaźniewicz *et al.*, 2003). Geochemically, they carry both suprasubduction and anorogenic signatures. The former relate these rocks to orogenic processes, the latter point to post-orogenic extension. Other geochemical features of the granitoids show that they developed from poorly evolved magmas which were generated by partial melting of ancient continental crust (ε_{Nd300} -6.0). The geochemistry of the granitoids and related volcanic rocks and the zircons inherited by them suggest that the magmas were derived from the lower/middle crustal sources which comprised Sveconorwegian (Grenvillian) and older Baltican crust of pelitic/greywacke/felsic composition, with some mantle component. The Variscan collision between Gondwana and Laurussia was among others accommodated by dextral wrenching along the TESZ. Such regime controlled intrusions of the granitoid magmas and caused the W–E directed extension which further promoted volcanic extrusions of rhyolites and ignimbrites that developed from more and more evolved and fractionated magmas. Accordingly, it is proposed that the ~300 Ma granitic magmas intruded into the attenuated Baltica (East European Craton) margin resulted from the heat flux generated by orogenic thickening and post-orogenic extension and mantle upwelling along TESZ. An outward advancement of the Variscan terranes over a mantle diapir resulted in the inward younging granite intrusions. Therefore, magmatism in the Harz Mts. postdated by 15–20 Ma the silicic plutonism/ volcanism in the TESZ in Poland and the "flare-up" volcanism in the North German-Polish Basin. Taking also into account the zircon data, the source material for granites in the Variscan foreland may have also come from the East Avalonian part of the Old Red Sandstone Continent and from the Scandian domain of the Caledonides which was drained southward to the Rheic Ocean opened to the S of Avalonia.

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Nature and timing of the Cadomian magmatism in the Brunovistulian Domain of the Eastern Bohemian Massif: new U–Pb zircon and Sr–Nd isotopic evidence

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The Brunovistulian Domain is interpreted as a product of the late Neoproterozoic magmatic activity which took place along the northern active margin of the Gondwana (Nance, *et al*., 1991). The geographical extent and duration of this Cadomian magmatism are still poorly constrained. Newly obtained LA ICP-MS zircon ages for three (meta-) granitoids from the Brno Massif (BM) and the Moravian Zone (MZ) together with their whole-rock and Sr–Nd isotopic compositions allow us to discuss the timing and nature of magmatic activity within this part of the Brunovistulian Domain.

New U–Pb dating of magmatic zircons from the western part of BM granite, the paraautochtonous orthogneiss from the core of the MZ and the allochtonous Bíteš orthogneiss yielded concordia ages of 601±3 Ma, 634±6 Ma and 568±3 Ma (2σ), respectively. These are interpreted as dating their Neoproterozoic magmatic protolith crystallization. No inherited zircon cores were detected in the BM granite. The MZ orthogneiss contains only one older (ca. 1670 Ma) grain, whereas the frequent inherited cores from the Bíteš orthogneiss show dominant age peak at ca. 1.7–2.1 Ga and local peaks at ca. 0.9–1.5 Ga and ca. 2.7 Ga and correspond to ages reported by Friedl *et al*. (2000). Geochemical and Sr–Nd isotopic data suggest that the BM granite came from a relatively juvenile crust, while the MZ and Bíteš orthogneisses were derived from ancient and geochemically evolved continental crustal segment. The variability in the Nd isotopic compositions is directly reflected by the two-stage Depleted Mantle Nd model ages (the BM granite: 1.33 Ga, the MZ paraautochtonous orthogneiss: 1.57 Ga, the Bíteš orthogneiss: 2.01 Ga).

The new geochronological, geochemical and Sr–Nd isotopic data provide an evidence for a long-lived magmatic activity within the Brunovistulian Domain. The differences in ages, presence of inheritance and isotopic composition of the Brunovistulian granitoids imply that the various crustal sources were included into the magmatic arc in course of the Cadomian arc-related crustal growth.

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The Podolsko complex, Bohemian Massif: a (U)HP suture zone assemblage or metamorphic core complex in the footwall of a large supracrustal detachment?

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The Podolsko complex is a high-grade assemblage exposed beneath a NW-dipping tectonic boundary of the upper-crustal Teplá–Barrandian unit with mid- to lower-crustal Moldanubian unit in central Bohemian Massif. The complex is made up of leucocratic and biotite migmatites (metatexites to diatexites) and granitic gneisses, but also contains small slivers of variably retrogressed granulites and mantle-derived rocks; peak pressures were estimated at 2.8 GPa (Kotková *et al*., 1997). To the E and SE, the complex is juxtaposed against another, Varied unit consisting of biotite migmatites with intercalations of marble, quartzite, and amphibolite, which is farther to S and SE juxtaposed against biotite–sillimanite paragneisses (Monotonous unit). The Podolsko complex and the surrounding units play an important role in understanding evolution of the Variscan deep crust: for instance, in a seminal concept of Tollman (1982) they have been interpreted as an inverted metamorphic stack with the Podolsko complex being a root zone of a huge Gföhl nappe transported eastward over the Moldanubian unit. In contrast, our new structural, geochronologic, and petrologic data suggests a polyphase tectonometamorphic history of the Podolsko complex and surrounding units. The U–Pb zircon ages obtained from migmatites and anatectic granites are compatible with a prolonged tectonomagmatic activity along the Teplá–Barrandian/Moldanubian boundary and indicate episodic remelting of Cambro–Ordovician crust with the main age clusters at around 480, 370–380, 350, and 339–340 Ma. These ages correspond to Ordovican rifting, Late Devonian and early Carboniferous arc plutonism, and granulite-facies metamorphism, respectively, documented elsewhere in the Bohemian Massif. Furthermore, our structural and magnetic fabric analysis recognized two main deformation events: ~E–W shortening overprinted by dominant and widespread vertical shortening, both sharing same ~N–S principal stretching direction and both synchronous with anatexis. Based on a combination of these data sets, we interpret the Podolsko complex as a metamorphic core complex exhumed to shallow depths beneath a crustal-scale normal shear zone. This detachment delineates the whole southeastern margin of the Teplá-Barrandian unit and accommodated collapse of the orogenic upper crust (Žák *et al*., 2012). The collapse triggered exhumation and widespread crustal melting in the footwall (the Podolsko complex) at around 340 Ma and extensively obliterated older (U)HP assemblages, leaving their extent and significance unresolved.

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