Field excursion guide

The excursion comprises four geological localities that serve as an introduction to the rock record of the consolidation of the Bohemian Massif during the Variscan orogeny (400–300 Ma; Stops 1–3) and its later coverage by sediments during the Cretaceous marine transgression (~100–85 Ma; Stop 4). Finally, there will be an opportunity for sightseeing in the town of Kutná Hora, a UNESCO World Heritage Site (Stop 5, unguided tour).

The geological excursion includes several short walks (no more than 3 km altogether; good walking shoes and long trousers are advisable) and more than two hours of bus travel. Some of the localities are situated near steep cliffs; please be mindful of your own safety and that of other participants.

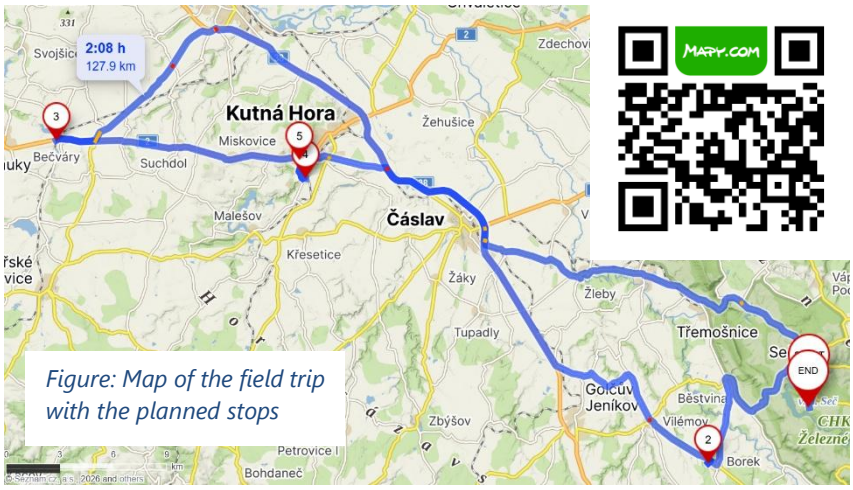


Figure: Map of the field trip with the planned stops

Formation of the Bohemian Massif

The Bohemian Massif is a large exposure of basement rocks covering most of the Czech Republic, and parts of Germany, Austria, and Poland. The dominant tectonic event shaping the Bohemian Massif was the Variscan orogeny (~400–300 Ma), driven by the convergence and collision of Gondwana and Laurussia during the closure of the Rheic and Saxothuringian oceans. This produced a complex collisional belt characterized by continental subduction, crustal thickening, high-pressure metamorphism, and voluminous magmatism. The orogenic belt that formed during the Variscan orogeny spanned Europe from the west to the east. Its remnants today form isolated massifs, including, besides the Bohemian Massif, the Vosges, Black Forest, French Massif Central and the Iberian System, and remnants are also found within the Alpine belt. Following the peak Variscan metamorphism and magmatism, the orogen collapsed (~320–250 Ma), resulting in large-volume post-orogenic magmatism, along with the formation of extensional basins filled with continental sediments (future carbon deposits).

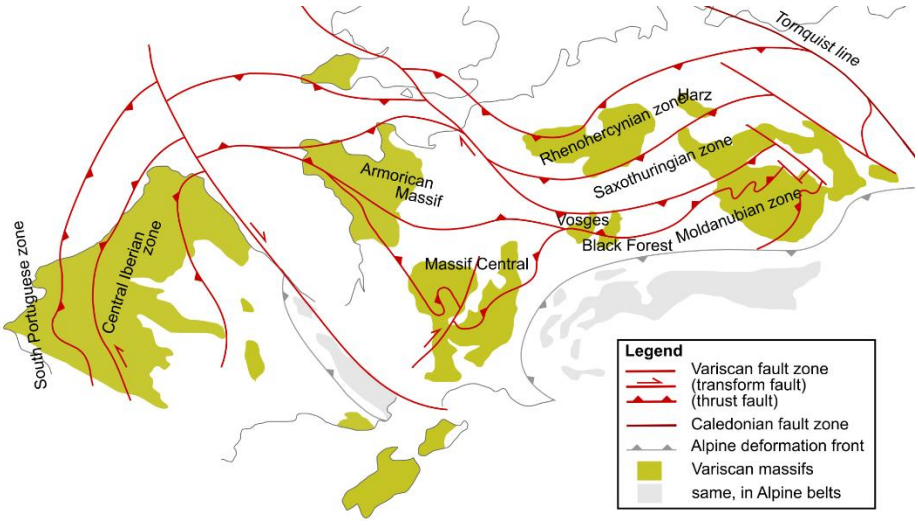


Figure: Map of the Variscan belt (from Wikipedia)

During the Mesozoic, the Bohemian Massif became a relatively stable part of the European continental interior. Long-term erosion reduced the former mountain chain to a low-relief landscape. Following an extended period largely devoid of sedimentary record, the most significant Mesozoic event was the Late Cretaceous marine transgression, during which the sea flooded large parts of the Bohemian Massif. A prolonged period of high sea level followed (~100–85 Ma), when extensive marine sediments were deposited. During this period, the resulting sedimentary basin accumulated up to 1,000 m of marine deposits. During the Paleogene and

Neogene, the Bohemian Massif responded to Alpine compression by episodic uplift, inversion of Mesozoic basins, and continental rifting associated with volcanism (e.g., the České středohoří volcanic complex, ~25–10 Ma).

In the Bohemian Massif, four Variscan lithotectonic units are distinguished: the Saxothuringian unit in the northwest, north and northeast (lower plate during the Variscan orogeny), the Teplá–Barrandian unit in the western and central part (crustal lid of the upper plate), the Moldanubian unit in the west and south (crustal root of the upper plate), and the Brunovistulian unit in the east (continental backstop). The field trip localities lie within the central part of the Massif, where the Teplá–Barrandian and Moldanubian units meet along a complex shear zone.

The Moldanubian unit represents the root of the Variscan orogenic crust now exhumed to the surface by erosion. It contains rocks that record high-pressure (HP) and high-temperature (HT) metamorphism and deformation: HP–HT **gneisses** and **granulites**, **eclogites**, **peridotites** and **pyroxenites**, some recording extreme peak conditions of up to >3 GPa and 900–1000 °C.

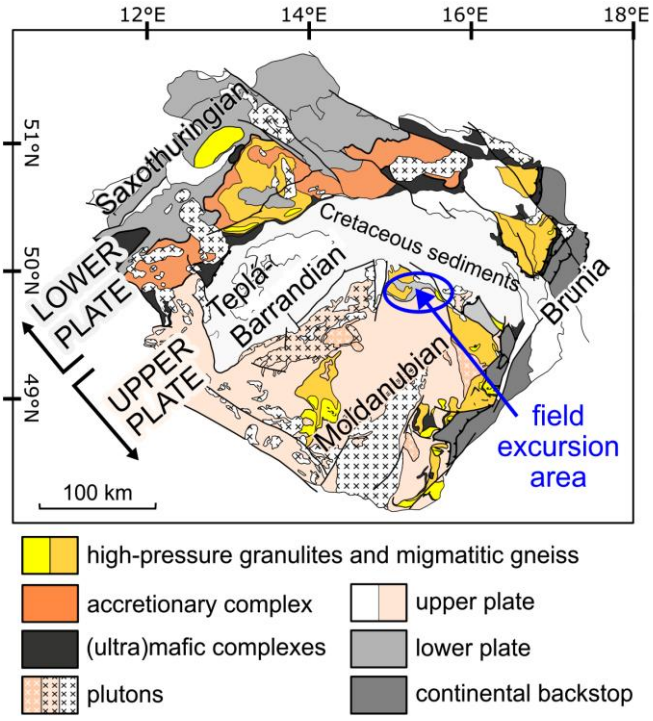


Figure: Map of the Bohemian Massif

Glossary

gneiss – Metamorphic rock characterised by compositional layering resulting from a penetrative deformation formed at high metamorphic grade.

granulite – Metamorphic rock formed at high-temperature conditions; it lacks hydrous minerals, and it is considered a residue after partial melting and melt extraction. It encompasses a range of rock compositions from **mafic** to **felsic**. Granulites are characteristic rock types of the lower crust.

eclogite – Mafic metamorphic rock, consisting mainly of minerals garnet and pyroxene (omphacite), and characterised by the absence of plagioclase. It is characteristic of high-pressure metamorphism, typically above 1.5 GPa. Mechanically strong, very dense and very durable.

peridotite – Ultramafic rock composed mainly of olivine and pyroxene. It is the dominant rock type of the Earth's upper mantle.

pyroxenite – Ultramafic rock composed predominantly of pyroxene minerals. It commonly occurs together with peridotite in the mantle.

felsic – Rock or mineral composition rich in silicon, aluminum, sodium, and potassium. Felsic rocks are typically light-colored and contain abundant quartz and feldspar.

mafic – Rock or mineral composition rich in magnesium and iron. Mafic rocks are typically dark-colored and contain minerals such as pyroxene, amphibole, and olivine.

Literature

Gerya T, Maierová P (2025) Modeling the Variscan Orogeny. Elements 21: 394–400.

Janoušek V, Hanžl P, Svojtka M, et al. (2020) Ultrapotassic magmatism in the heyday of the Variscan Orogeny: the story of the Třebíč Pluton, the largest durbachitic body in the Bohemian Massif. Int J Earth Sci (Geol Rundsch) 109: 1767–1810.

Matte P (2001) The Variscan collage and orogeny (480–290 Ma) and the tectonic definition of the Armorica microplate: a review. Terra Nova 13: 122–128.

Moyen J-F, Guy A, Fiannacca P, et al. (2025) Granites and the Nature of the Variscan Crust. Elements 21: 415–421.

Schulmann K, Catalán JRM, Schaltegger U (2025) Variscan Orogeny: A Three Oceans Problem. Elements 21: 387–393.

Stop 1 - Felsic rock metamorphism and melting

Description (Oheb orthogneiss to migmatite)

Oheb orthogneiss is a representative of metamorphic rocks of the area around the Seč Reservoir, called the Oheb Crystalline Complex. It formed during regional metamorphism of a magmatic rock (a granitic/tonalite protolith). It reached HP–HT conditions with peak temperatures of ~750°C–870°C and pressures of ~1.5–1.9 GPa. This unit represents a deeply subducted continental crust that underwent intense Variscan regional metamorphism and partial melting.

This **orthogneiss** is grey to pinkish in colour, consisting of K-feldspar, quartz, kyanite and mica flakes (light mica – muscovite, dark mica – biotite). Gneissic banding is the diagnostic feature here. It shows alternation of light-coloured and dark-coloured bands. Several processes contribute to gneissic banding. Metamorphic differentiation segregates minerals during prolonged heating, concentrating quartz and feldspar (light-colored minerals) in one layer and mafic (dark-colored) mineral phases in another. Any older layering like sedimentary bedding, igneous compositional variation, or results of earlier deformation gets reoriented parallel with the dominant strain. At a higher, supra-solidus temperature, the felsic layers begin to melt and the rock then evolves into **migmatite**.

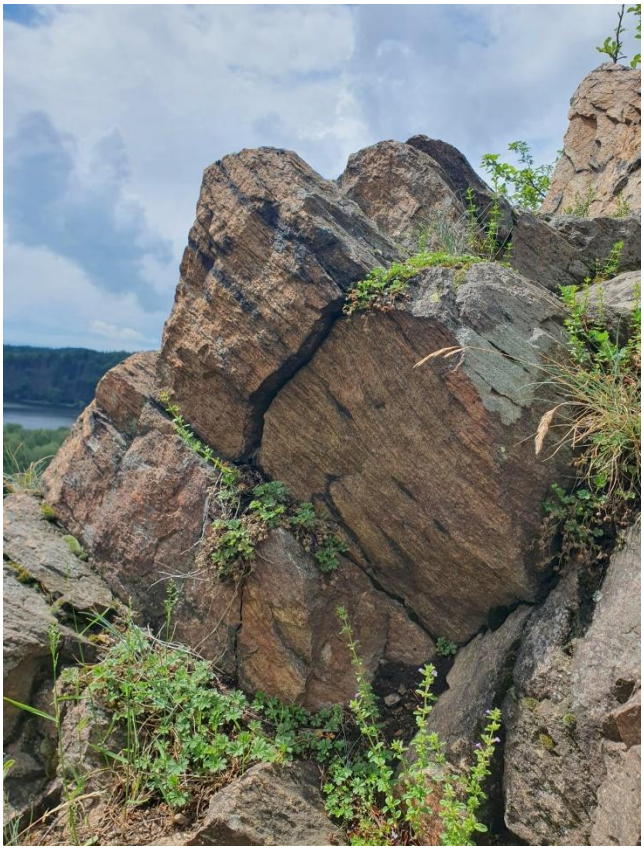


Figure: Strongly foliated Oheb orthogneiss

Interesting fact: The Oheb rocky spur received its name from a change in the course of the Chrudimka River ("oheb" means "bend" in Czech): the river bends here so sharply that it resembles a bent elbow. This feature was created by a phenomenon known as stream piracy. It resulted from the movement of individual crustal blocks during the Tertiary Period. The block of the Iron Mountains was uplifted, and the stream was eroding the rocks of the uplifted block faster than the surrounding rocks. It gradually propagated forward until it reached the paleo-Chrudimka River, which had previously flowed northwestward, and they merged.

Features to observe and topics to discuss

Rock deformation

Rock structure can be used to reconstruct the rock's deformation history. Ductile deformation typically creates wavy, curved structures known as folds and gives metamorphic rocks their striped, layered textures – **foliation**. Brittle deformation is typically observed as faults, cracks or joints. By measuring the orientation of faults in the upper crust or mapping foliations and folds of an ancient migmatite or gneiss in a mountain core, we can distinguish different deformation episodes and infer the direction of motion and the amount of strain.

Determination of pressure–temperature conditions based on mineral assemblage

The chemical elements inside minerals rearrange themselves in predictable ways as pressure (depth) and temperature change. Therefore, different mineral assemblages and mineral compositions reflect different pressure-temperature (P–T) conditions. Estimation of P–T conditions is called thermobarometry. Geobarometers typically rely on net-transfer reactions, where minerals break down completely to form entirely new, denser mineral structures under pressure. Geothermometers typically rely on cation exchange reactions, where two or more elements with similar sizes and electrical charges swap places between two minerals. For example, in the Oheb orthogneiss, there is a peak mineral assemblage of garnet + kyanite + K-feldspar + quartz. The temperature clue is the presence of kyanite alongside K-feldspar, which proves that the rock was

hot enough to melt via dehydration melting, pinning temperatures above 750 °C. The pressure clue is that the rock completely lacks plagioclase feldspar, and the aluminosilicate mineral is kyanite (stable under high pressure) rather than sillimanite (low pressure). This pins the pressure above 1.5 GPa.

Melting in crustal rock types

Crustal rocks are composed of a mixture of different minerals. As a result, they do not melt entirely at a single temperature, but they undergo partial melting – anatexis – with the melt fraction increasing over a range of conditions. In a typical crustal rock, the more felsic components, rich in quartz and feldspar, begin to melt first, whereas more mafic minerals may remain solid. Consequently, melting initially affects only part of the rock, producing a mixture of melt and residual solid minerals. The temperature at which the first melt appears (the solidus) depends on several factors. Fluid-present (or "wet") melting occurs in the presence of free water or fluids trapped in the rock pore spaces or cracks. The presence of water weakens the silicon-oxygen bonds that hold mineral crystals together, allowing melting to begin at temperatures as low as ~650 °C. In contrast, dehydration melting involves breakdown of hydrous minerals (e.g. mica) and formation of new so-called peritectic minerals (e.g. garnet or orthopyroxene). This occurs at higher temperatures (~750 °C to 900 °C) when the hydrous minerals become unstable and release their structurally bound water. The released water then promotes melting of the rock. The Oheb orthogneiss is an example of dehydration melting of white mica (muscovite), whilst producing peritectic kyanite/sillimanite.

Glossary

orthogneiss – Typically light-colored felsic rock that formed during regional metamorphism and deformation of granitoids. Its light and dark layers ("bands") reflect the segregation of different minerals during metamorphism.



Figure: Partially molten orthogneiss with light-coloured neosome parts and dark-coloured melanosome parts

migmatite – A migmatite is a "mixed rock" that falls between metamorphic rock and igneous rock. It is created when a rock (like gneiss) undergoes partial melting (anatexis). Migmatite consists of two main, contrasting parts: (i) Neosome (i.e., the newly formed, modified part of the rock during the melting event. It further divides into leucosome (light-colored, igneous-textured part representing the crystallized melt) and melanosome (dark-colored, rich in mafic minerals like biotite or amphibole that did not melt, typically forming a border around the leucosome). (ii) Mesosome (or paleosome), which is the unmodified parent metamorphic rock that completely escaped the partial melting process. There are many types of migmatites, depending on the amount of melt and structures.

foliation – distinct banding texture found in metamorphic or magmatic rocks. It develops when a rock is subjected to deformation, causing its minerals to realign parallel to one another. Foliation is not the result of sedimentary layering.

Literature

Hasalová P, Schulmann K, Lexa O, et al. (2008) Origin of migmatites by deformation-enhanced melt infiltration of orthogneiss: a new model based on quantitative microstructural analysis. Journal Metamorphic Geology 26: 29–53.

Hasalová P, Štípská P, Powell R, et al. (2008) Transforming mylonitic metagranite by open-system interactions during melt flow. Journal Metamorphic Geology 26: 55–80.

Sawyer EW (2008) Atlas of Migmatites, Canadian Science Publishing.

Weinberg RF, Vernon RH, Schmeling H (2021) Processes in mushes and their role in the differentiation of granitic rocks. Earth-Science Reviews 220: 103665.

Stop 2 - Subduction zone rock assemblage

Description (Borek serpentinite quarry)

The outcrop is an abandoned quarry in a large body of *serpentinized peridotite (serpentinite)*. The serpentinite was quarried from the Second World War until 1992. In addition to the peridotite, the quarry exposes *eclogite* and *felsic gneiss*. The geological map of the area shows the relations between the different rock types: the serpentinite and the eclogite are associated as a lens embedded in the felsic gneiss.

- The *serpentinite* is visible on the walls of the quarry. It is an ultramafic mantle rock (peridotite) that underwent a specific type of alteration known as serpentinization. During serpentinization, the minerals olivine and pyroxene are transformed into hydrous minerals of the serpentine group. At this outcrop, the glossy dark serpentine with irregular texture gives the rock its characteristic appearance. The specific ultramafic composition of serpentinite results in magnesium-rich, calcium-poor soils that are challenging for most plants. As a result, rare plant species adapted to such conditions can be found at the locality, including the fern Asplenium cuneifolium, which grows exclusively on serpentine soils.
- The *eclogite* is most easily found as pebbles paving the path next to the quarry. It contains abundant garnet crystals in a green matrix composed of omphacite (a type of pyroxene), partially replaced by a secondary mineral assemblage. These dense minerals are characteristic of elevated pressure.
- The *felsic gneiss* is exposed locally in the quarry. It is recognizable by its light colour and the alteration profile, typical for the weathering of granitoids rocks.

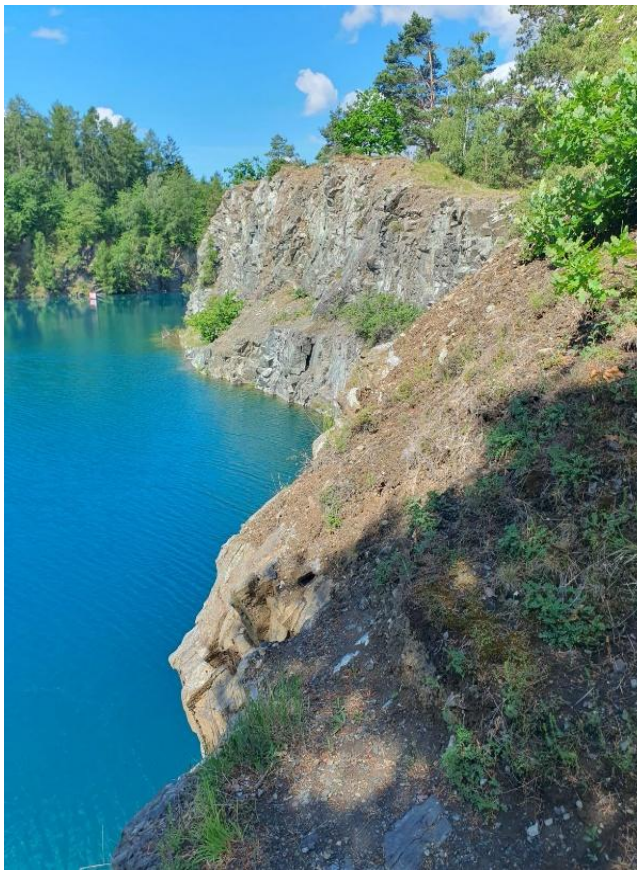


Figure: The Borek quarry

The geochemical composition of the serpentinized peridotite suggests formation in a subduction zone, probably within the subcontinental lithospheric mantle overlying the subduction zone. The serpentinite contains spinel, but no evidence of garnet was found, suggesting equilibration pressures between ~1.0–3.0 GPa. Garnet in the eclogite preserves a compositional zoning related to burial during subduction. Thermobarometric methods indicate peak metamorphic conditions of ~1.3–1.5 GPa and 630–655 °C.

Features to observe and topics to discuss

Rock strength affected by hydrous minerals

Rock hydration and the growth of hydrous minerals, such as mica and serpentine, substantially reduce rock strength. The sheet-like crystal structures of these minerals contain strong bonds within individual sheets but much weaker bonds between them. As a result, their deformation occurs by sliding along these planes.

Serpentinite is produced by hydration of ultramafic (i.e., mantle) rocks that leads to the formation of the mineral serpentine. Serpentinite then commonly forms mechanically weak horizons in subduction zones and major fault systems, where it promotes strain localization and decoupling between tectonic plates.

In contrast, eclogite consists mainly of garnet and pyroxene, both mechanically strong minerals with little or no structurally bound water. Consequently, eclogite is commonly one of the strongest lithologies present in subduction complexes. It often behaves as a rigid inclusion within weaker surrounding rocks.



Figures: Left – Fine-grained eclogite dominated by minerals garnet, pyroxene, and amphibole (formed during a later stage of metamorphism). Right – Serpentinized peridotite

Juxtaposition of crustal and mantle rocks in the Bohemian Massif

The Moldanubian domain, a former core of the Variscan orogen, is a geologically complex region comprising units of contrasting characteristics and origins. It dominantly consists of crustal rocks that record pressures and temperatures corresponding to the root of thickened orogenic crust. However, the Moldanubian domain also contains significant occurrences of highly metamorphosed crustal rocks in close spatial association with mantle-derived rocks, indicating a more complex geological history.

The highest pressures recorded by the crustal rocks exceed 3.5 GPa, corresponding to mantle depths and indicating deep subduction of continental crust. The associated mantle rocks record similar or higher peak P–T conditions, reaching 4.0–4.5 GPa and approximately 900–1000 °C. Such a rock association is characteristic of a subduction-zone setting, where rocks at a continental margin are carried to great depths and subsequently, together with entrapped pieces of mantle, exhumed back due to their buoyancy. However, contrary to what would be expected in such a scenario, the (U)HP rock complexes in the Moldanubian domain do not form a linear belt marking a boundary between distinct paleogeographic domains. Instead, they occur as scattered, commonly dome-shaped structures. It has therefore been proposed that these (U)HP rocks originated in a subduction zone located further to the north (in present-day coordinates). Instead of coming back to the surface along the subduction zone, the subducted rocks were added to the base of the upper plate (the future Moldanubian domain). The (U)HP complexes occur as domes surrounded by lower grade continental rocks suggesting that they were subsequently exhumed as diapirs rising through the upper plate.

The Borek serpentinite–eclogite lens is located in a near vicinity (~1 km) of such a HP–HT rock complex, but it records significantly lower pressures and temperatures. Its role and position during the Variscan orogeny are still debated.

Literature

Medaris LG, Fournelle JH, Ghent ED, et al. (1998) Prograde eclogite in the Gföhl Nappe, Czech Republic: new evidence on Variscan high-pressure metamorphism. Journal of Metamorphic Geology 16: 563–576.

Medaris G, Wang H, Jelínek E, et al. (2005) Characteristics and origins of diverse Variscan peridotites in the Gföhl Nappe, Bohemian Massif, Czech Republic. Lithos 82: 1–23.

Nahodilová R, Štípská P, Powell R, et al. (2014) High-Ti muscovite as a prograde relict in high-pressure granulites with metamorphic Devonian zircon ages (Běstvina granulite body, Bohemian Massif): Consequences for the relamination model of subducted crust. Gondwana Research 25: 630–648.

Nahodilová R, Hasalová P, Štípská P, et al. (2020) Exhumation of subducted continental crust along the arc region. Gondwana Research 80: 157–187.

Stop 3 - Garnet peridotite

Description (Bečváry quarry)

The outcrop is a small abandoned quarry. The excavation exposed a *garnet peridotite* containing layers and lenses of *garnet clinopyroxenite* and *eclogite*. All the rock types are affected by a variable degree of retrogression, including the typical serpentinisation of the peridotite.

- The *garnet peridotite* is the darkest facies of the quarry. It is composed of garnet crystals (mm to cm in size) in a dark green matrix, essentially composed of serpentine minerals. The serpentine mineral provides a distinctive shiny aspect and flaky texture to the rock.
- The *garnet clinopyroxenite* is composed of bright-green sodic-rich diopside pyroxene associated with mm-sized garnet.
- The *eclogite* is a mixture of garnet and pyroxene (omphacite**)**. It is the most competent rock on the outcrop. The omphacitic pyroxene and its breakdown products are usually darker than the pyroxene of the clinopyroxenite, as a result, the rock colour is intermediate between the dark peridotite and the bright pyroxenite.

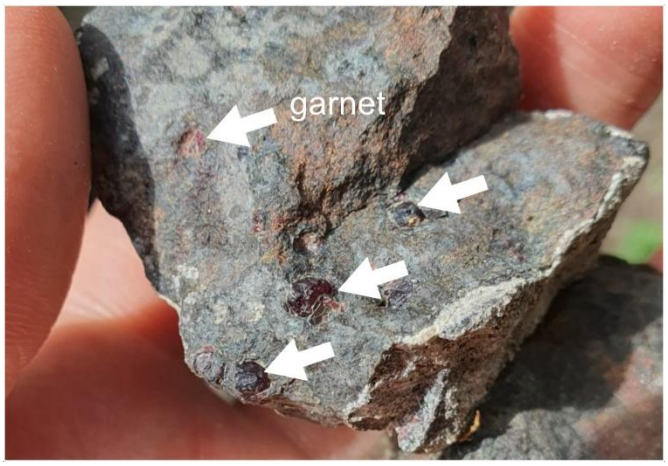


Figure: Garnet peridotite

Garnet peridotites are typical rocks of the Earth's upper mantle. The association with garnet clinopyroxenite and eclogite is common in several orogens worldwide, but their origin is debated. Both clinopyroxenite and eclogite could derive either from the oceanic crust during subduction, or from the high-pressure crystallisation of basaltic melts. Solving the origins of eclogite and clinopyroxenite is important because these contrasting scenarios potentially occur in very different geodynamic settings.

All the rock types from this locality contain garnet, which is a typical phase of high-pressure metamorphism in mafic and ultramafic rocks, like eclogites and peridotites. In mafic rocks, garnet typically occurs above 1–1.2 GPa and omphacite commonly grows around 1.5–2 GPa. In ultramafic rocks, garnet is typically stable above 2.5–3.0 GPa. For this locality, thermobarometers based on garnet and clinopyroxene chemical compositions in the garnet clinpyroxenite suggest P–T conditions in the range 1.5–2 GPa and ~900 °C, corresponding to a relatively shallow mantle environment, although deeper than the rocks from Stop 2.

Determining the origin of these rock types requires the careful application of petrography and geochemical methods. The original assemblage of the *peridotite* comprised olivine, garnet, orthopyroxene and a non-negligible amount of clinopyroxene, indicating a lherzolite peridotite composition. Lherzolites are fertile mantle rocks, meaning they are rich in elements that readily enter the melt upon partial melting. Their composition is not typical of the continental mantle, which is predominantly harzburgitic and therefore more depleted in melt-forming components. Small multiphase solid inclusions in garnet are interpreted as former melts that infiltrated and refertilised the mantle reservoir. The inclusions contain Fe-, Mg- and Ti-rich minerals such as olivine, spinel and ilmenite, suggesting a basaltic composition of the melt. Trace-element and isotope geochemistry suggest that this melt was produced in another mantle source previously contaminated by a crustal component, most likely brought to the mantle during subduction.

The *garnet pyroxenite* is interpreted as a rock of the oceanic crust that was subducted and embedded in the garnet peridotite at high pressure. The *eclogite* is interpreted as the crystallisation of a basaltic melt during this subduction. Garnet hosting the melt inclusions in the garnet peridotite is a direct witness of these events. It was dated at ~422 Ma, corresponding to the closing of the Saxothuringian Ocean that later led to the Variscan orogeny in the Bohemian Massif.

Topics to discuss

Garnet occurrences and uses

Garnet is both "common" and "uncommonly useful" (Baxter et al., 2013). Natural garnet is a silicate mineral with a wide range of composition. It is stable over vast conditions and in a large variety of geochemical environments. For these reasons, it finds many applications in studying natural processes, in technical and industrial processes, and carries cultural importance.

Garnet is widespread in crustal rocks, though most Earth garnet occurs in the upper mantle. Garnet occurs especially in metamorphic rocks where it is stable in a wide variety of rock chemical compositions and in a broad range of P–T conditions from greenschist facies (~400 °C, 0.4 GPa) to UHT or UHP conditions, up to the mantle transition zone (>1400 °C and 25 GPa). Garnet is also found in magmatic rocks and, owing to its resistance to weathering, in sedimentary rocks as a detrital mineral.

Garnet has the general formula $X_3Y_2Si_3O_{12}$ where X is eightfold-coordinated and filled by a solid solution of divalent Fe, Mg, Ca, Mn, and Y is a sixfold-coordinated site commonly filled by trivalent Al, in cases substituted by Fe^{3+} or Cr. Garnet structure results in higher cation coordination numbers than most usual silicates, making garnet hard, dense, little compressible and increasingly stable with pressure, while its compositional range results in a remarkable variety of colours. Because of these properties, garnet was historically and is still used as an abrasive in the industry, or as a gemstone in jewelry and decorative arts. Its magnetic, lasing, and ionic conductivity properties can be used in electronics, lasers and batteries.

In geology, garnet properties have critical implications for geodynamics; for example, the high density of garnet and its increasing stability at high pressure drive the densification of rocks at depths and thereby contribute to driving plate tectonic processes like subduction or delamination.



Figure: Czech garnet as a gemstone

Garnet in metamorphic petrology

The geochemical characteristics of garnet prove extremely useful in documenting the environmental conditions and timing of geodynamic processes. During metamorphism, equilibrium at distinct P–T conditions is achieved by varying mineral compositions and proportions. Garnet is subject to Fe–Mg substitution on the X site, and Fe–Mg partitioning with coexisting phases depends on P–T conditions. This partitioning dependence on temperature can be used to develop thermometers. The same principle applied to the partitioning of Ca was used to develop barometers. This way, garnet composition allows for the determination of metamorphic conditions.

The accumulation of mineral thermodynamics data allowed the construction of thermodynamic datasets that are used routinely to carry out phase equilibrium modelling of rock minerals, including garnet. Garnet commonly occurs as a zoned crystal, showing compositional variations from core to rim. These variations are related to varying mineral equilibrium as the P–T conditions changed during garnet growth. They can be used to track the P–T evolution in modelled phase equilibrium P–T diagrams.

The compositional zoning tends to homogenise by diffusion at high temperature, resulting in diffusion profiles that can be modelled to estimate the duration of metamorphic events. Finally, garnet also incorporates trace concentrations of radioactive isotopes of Lu and Sm, decaying into isotopes of Hf and Nd, respectively. Measurements of these parent–daughter isotopic ratios

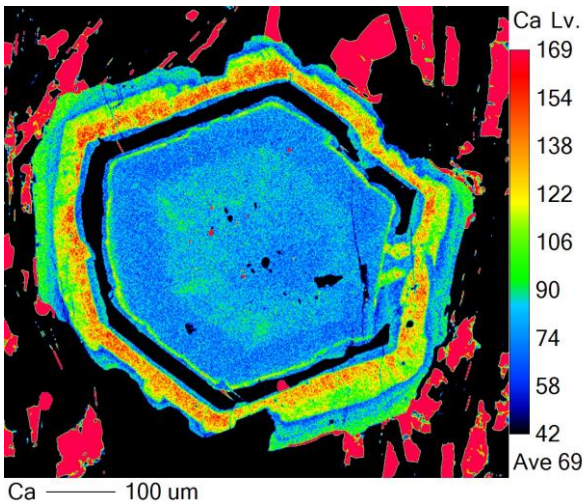


Figure: X-ray map for calcium in garnet

allow for the determination of the absolute age of garnet crystallisation. Altogether, these methods help decipher the pressure–temperature–time evolution of metamorphic rocks.

Comparison of the Borek and Bečváry peridotites

Serpentinites from Borek (Stop 2) and Bečváry (Stop 3) exhibit significant petrographic differences. The Borek serpentinite contains spinel, typical of mantle between 1.0 and 3.0 GPa, while the Bečváry one contains garnet, characteristic of pressure higher than 2.5–3.0 GPa. Furthermore, P–T estimates in the eclogite in Borek quarry yield a temperature of 630–655 °C at high pressure (~1.3–1.5 GPa), while the garnet clinopyroxenite in the Bečváry quarry equilibrated at a significantly higher temperature of ~900 °C (at 1.5–2 GPa). These contrasting P–T conditions suggest the existence of two distinct units. It remains unclear whether the two units belong to a unique or several distinct subduction system(s).

Literature

Ackerman L, Kotková J, Čopjaková R, et al. (2020) Petrogenesis and Lu–Hf Dating of (Ultra)Mafic Rocks from the Kutná Hora Crystalline Complex: Implications for the Devonian Evolution of the Bohemian Massif. Journal of Petrology 61: egaa075.

Baxter EF, Caddick MJ, Ague JJ (2013) Garnet: Common Mineral, Uncommonly Useful. Elements 9: 415–419.

Beard BL, Medaris LG, Johnson CM, et al. (1992) Petrogenesis of Variscan high-temperature Group A eclogites from the Moldanubian Zone of the Bohemian Massif, Czechoslovakia. Contr Mineral and Petrol 111: 468–483.

Medaris LG, Beard BL, Johnson CM, et al. (1995) Garnet pyroxenite and eclogite in the Bohemian Massif: geochemical evidence for Variscan recycling of subducted lithosphere. Geol Rundsch 84: 489–505.

Svojtka M, Ackerman L, Medaris LG, et al. (2016) Petrological, Geochemical and Sr–Nd–O Isotopic Constraints on the Origin of Garnet and Spinel Pyroxenites from the Moldanubian Zone of the Bohemian Massif. J Petrology 57: 897–920.

Stop 4 - Marine sedimentary sequences

Description (Kutná Hora geopark)

The Geopark was established in 2014 and comprises over 40 large rock specimens in an abandoned quarry. The exhibition presents a wide collection of rocks from the Kutná Hora Crystalline Complex and its surroundings and documents its intricate geodynamic history.

The quarry itself exposes a striking geological feature on its wall: the Cretaceous **unconformity**. Here, flat-lying Cretaceous (~100–90 Ma) **calcareous sandstones** rest directly on the tilted gneiss with **boudins** of mafic rocks. The gneiss results from metamorphism and deformation of Proterozoic (~600–700 Ma) granitic rocks during the Variscan orogeny (~350 Ma). The unconformity between the gneiss and sediments encapsulates ~250 million years of missing geological record, the period during which the Variscan orogen was eroded to a **peneplain** and the metamorphic basement was progressively unroofed.

Under the action of tectonics and climate, the Cretaceous sea eventually flooded the eroded landscape (the peneplain), depositing various types of sediments. Near the coast, waves and currents deposited pebbles and coarse sands that later became **conglomerates** and sandstones. Beach conglomerates along the base of the Cretaceous sequence contain rounded cobbles of the underlying gneiss, showing that the basement was exposed on the seafloor and actively eroded by wave action as the Cretaceous sea transgressed across the Bohemian Massif. Later, when the sea got deeper, the water also got calmer, and fine mud and carbonate particles were deposited. In some areas, the accumulation of shells and skeletal fragments from marine organisms produced calcareous sandstones and limestones. The sea was shallow, warm, and characterized by high biological productivity. Its deposits now form the "Kutnohorská **opuka**", the principal building stone of Gothic churches and patrician houses throughout the town of Kutná Hora and a common historical building stone in Prague as well.

Glossary

unconformity – A surface separating older rocks from younger rocks that shows a gap in geological time, often because erosion occurred. Unconformities typically occur between old, folded rocks and younger, unfolded ones. For this reason, in the past, geologists used unconformities to identify orogenies, or their phases.

calcareous sandstone – A sandstone that contains a significant amount of calcium carbonate. It often formed from sand mixed with shell fragments or other carbonate-rich material.

boudin – A word of French origin ("sausage") describing a lens of rock formed when a stronger rock layer is stretched and breaks into separate blocks within a weaker surrounding rock.

peneplain – A broad, nearly flat landscape produced by very long periods of erosion. It represents the final stage of landscape leveling, although most peneplains are later uplifted and dissected by rivers.

conglomerate – A sedimentary rock made of rounded pebbles, cobbles, or larger rock fragments cemented together. The rounded shape of the fragments is a result of their transport by water before deposition.

"opuka" – A light grey or beige sedimentary rock with a fine-grained, porous texture. It consists mainly of calcium carbonate derived from microscopic marine organisms, together with varying amounts of silica and clay minerals. Although relatively soft when freshly quarried, it hardens after extraction, making it a durable building stone. The durability of the rock is enhanced by the presence of microscopic siliceous sponge spicules—tiny needle-like skeletal elements of marine sponges.



Figure: Quarry walls with the contact between the Variscan gneiss and the overlying Cretaceous sediments. The quarry hosts a geological exhibition (boulders in the front).

Literature

Uličný D, Laurin J, Čech S (2009) Controls on clastic sequence geometries in a shallow-marine, transtensional basin: the Bohemian Cretaceous Basin, Czech Republic. Sedimentology 56: 1077–1114.

Laurin J, Uličný D, Čech S, Trubač J, Zachariáš J, Svobodová A (2021) Chronology and Eccentricity Phasing for the Early Turonian Greenhouse (~93–94 Ma): Constraints on Astronomical Control of the Carbon Cycle. Paleoceanography and Paleoclimatology 36, e2020PA004188.

Stop 5 - Historical town Kutná Hora (unguided sightseeing)

Kutná Hora has been a UNESCO World Heritage Site since 1995 because of its outstanding architecture and its influence on architectural developments in other Central European city centres. The historic town centre is also protected as an urban monument reservation, the fourth largest in the Czech Republic.

Kutná Hora was one of the most important historic mining towns in Europe. During the 13th and 14th centuries, rich silver deposits discovered beneath the area transformed the town into a major economic center of the medieval Czech Kingdom. Mining began on a large scale in the late 1200s. The town's prosperity led to the establishment of the royal mint, where the Prague groschen silver coins were produced. The palace where the mint resided was named Italian Court ("Vlašský dvůr") after the Italian experts who were at the forefront of the minting reform. Currently, the building serves as a museum of coin minting. The historical town center also hosts the Museum of Silver in the so-called Stone House ("Hrádek"). Visitors can explore exhibitions on ore formation, mining technology, and the economic significance of silver.





Figures:
Top – Stone House ("Hrádek") hosting Czech Museum of Silver
Left – Italian Court ("Vlašský dvůr")

The silver ores of Kutná Hora occur within metamorphic rocks of the Bohemian Massif. The deposits are primarily hydrothermal veins containing minerals such as galena (lead sulfide), sphalerite (zinc sulfide), pyrite, and silver-bearing minerals. These ore veins formed when hot mineral-rich fluids circulated through fractures in the bedrock and precipitated metals as they cooled. Kilometers of underground workings in the source rock were excavated, some reaching depths of several hundred meters.

St. Barbora's Church is the most famous landmark of Kutná Hora and one of the finest examples of Late Gothic architecture in Central Europe. Construction began in 1388, at a time when the town was flourishing thanks to its silver mines, and continued for more than 500 years. Unlike many great medieval churches, it was not founded by a king or bishop but largely financed by the wealthy mining community, making it a powerful symbol of the town's prosperity and independence. The church is dedicated to Saint Barbora, the patron saint of miners, engineers, and others working in hazardous professions.



Figure: St. Barbora's Church



Figure: Map of the historical center with the locations of St. Barbora's Church (1), Stone House with Czech Museum of Silver (2), Italian Court (3) and the Geopark (4).

Kutná Hora https://kutnahora.net/en/ https://en.wikipedia.org/wiki/Kutn%C3%A1_Hora
Italian Court ("Vlašský dvůr") https://kutnahora.net/en/italian-court/
Stone House ("Hrádek") https://kutnahora.net/en/stone-house/
Czech Museum of Silver https://www.cms-kh.cz/eng