Summary

Calcic-iron skarns are one of the characteristic part of the regional metamorphic complexes of the Bohemian Massif. Their mineral assemblages, structures and significant enrichment of Ca, Al and Fe were previously interpreted to be primary (exhalation sediment) or secondary (metasomatic carbonates). In this project, which consists of three sub-studies will focus on the geochemical composition of skarn as the main arguments for the discussion of their origin.

Malešov deposit belongs to the typical calcic-iron skarns whose mineral assemblages are not very different from similar skarns associations in the Bohemian massif. It consists of lenticular body that is stored in gneiss and migmatites of the Kutná Hora crystalline complex. On the deposit prevails garnet-pyroxen skarn, less abundantly represented garnet and magnetite skarns and skarns replacement by amphibole or epidote. Fine-grained garnet skarns are formed by isotropic dark red garnet (Adr17.6Prp0.3), while in massive garnet rocks garnet grains form the core (Adr13.3Prp2.5), which envelop newly formed garnet (Adr28.6Prp1.6). In association with them is often pyroxene (Hd60.90) which can be replaced by hastingite amphibole composition. Other minerals present are magnetite, Fe-epidote, calcite and albite. Magnetite and pyroxene skarns are characterized by low concentrations of HFSE, Y, alkalis and P. Very low are their concentrations of Al2O3 (up to 1.5 wt.%), MnO (<0.2 wt.%) and REE (4.4 to 13.1 ppm). The garnet types are represented in the higher concentration of HFSE, Al (Al2O3 = 5.8 to 10.4 wt.%) and REE (44.1 to 71.6 ppm), the concentration of alkali and phosphorus are comparable (≤0.1 wt.%). In epidote skarns excess concentration of HFSE, Al and REE variations in other types. For the skarns with content of garnet are typical significant positive Eu anomalies. Ce anomalies in all skarn types are missing or very mild. Variation of major elements, especially aluminum, phosphorus and alkali exclude the share of metalliferous (emission) sediments on the chemical composition of the skarns. Absolute concentration of HFSE, Al and REE give rise to the fact that precursor of skarns was variable mixture of siliciclastic rock and component depleted of HFSE. Occurrences of carbonate rocks in association with skarns, calcium-iron mineralogy and low HFSE observed in the iron-rich skarns suggests that HFSE-depleted component included carbonate rocks. Most of titanium and aluminum incorporated into skarn minerals were derived from clastic components of protolith while most of Fe, Mn, Ca and Mg either originates from the chemical sedimentary component or were brought during metasomatic processes. Calculated mass balance for the defined composition skarn precursors show that must occur primarily to the contribution of Fe, Mg and Mn, while the calcium and LILE often occurred their leaching. Variation of major elements, HFSE patterns and relationships between them, or mass balance shows that skarns include a mixture of siliciclastic and carbonate sediments that have been subjected to post-deposition alteration (metasomatic) and subsequent regional metamorphism.

In the Svratka Unit is located in the area bounded by municipalities Krouna - Svratouch - Čachnov atypical skarns in conjunction with calc-silicate rocks (mainly erlans) and also in spatial association with mineralized occurrences (Ruda at Čachnov). Skarns mineral
association has a few differences from the mineral associations calcic-iron skarns in other units of the Bohemian Massif: abundant minerals of epidote group, in the nuclei epidote grains is a grain of allanite and component of garnet-pyroxene association is a small amount of plagioclase, that is present without the spatial relationships of the pegmatite veins. The main mineral phase calc-silicate rocks is clinopyroxene, plagioclase, hornblende, quartz ± garnet. In all rocks is an important accessory minerals titanite. Results of analyzes of rocks define four groups of rocks, which combines a striking linear trend: orthogneiss, calc-silicate rocks, calc-silicate rocks with garnet and garnet-pyroxene skarns. Calc-silicate rocks are characterized by relatively high contents of SiO$_2$ (60-68 wt. %) and alkalis (Na$_2$O ~ 5 wt.%; K$_2$O ~ 1.6-2.2 wt. %). As compared with the garnet-pyroxene skarns are poor calcium and iron. They are significantly enriched in HFSE (mainly Al and Ti), Ba and REE. Calc-silicate rocks with garnet differs from calc-silicate rocks s.s. elevated concentrations of Ca and Fe and decrease in alkaline. Garnet-pyroxene skarns from similar mineral associations in the Czech massif varies relatively high MnO (0.58 to 0.63 wt. %), which was probably brought together with Fe rich fluid solutions. Concentration of HFSE and REE are in them low. Garnet-pyroxene skarns beyond variations immobile elements in carbonates and lies at the interface between them and the average sediments of upper continental crust and continental crust.

High concentrations of immobile elements in calc-silicate rocks can not be explained by mixing with a significantly depleted end member such as carbonate. Variations in the content of CaO, FeO, SiO$_2$ and alkali shows that garnet-pyroxene skarns and quartz-feldspar rocks form the end members of the mixing line and calc-silicate rocks formed their variable mixing. Slightly negative Eu anomaly of calc-silicate rocks can be explained by mixing positive Eu anomalies garnet-pyroxene skarns with significant negative anomalies quartz-feldspar rocks, while Ce anomalies, typical for metalliferous (exhalation) sediments is identical in all rocks mild or almost absent. Temperature-pressure phase diagrams and univariant equilibria consistently shown that garnet-pyroxene skarns with epidote formed in a wide field of pressure-temperature conditions (450-750 °C, 5-18 kbar). Extensive field stability of the three phases shows that garnet, clinopyroxene and epidote were found in association already common for peak metamorphic conditions. In other calc-silicate rocks with minerals is imbalanced and can not use them to determine temperature-pressure conditions. Calc-silicate rocks probably formed when tectonic deformation during exhumation. Tectonic deformation caused deformation mixing at the contact between garnet-pyroxene skarns and quartz-feldspar rocks, which led to the mylonitised calc-silicate rocks consisting of fine grained bands with varying grain size and mineral components. Garnet-pyroxene skarns formed metasomatic processes with similar precursors comparable to skarns elsewhere in the Bohemian Massif.

Magnetite-rich skarns in the Bohemian Massif frequently occur in supracrustal volcanosedimentary sequences, metamorphosed up to greenschist, amphibole or eclogite facies. Texture of magnetite skarns is massive or banded, consisting of clinopyroxene, garnet, amphibole and ore minerals, mainly magnetite. At the electron microprobe analyzed 123 magnetite grains from 12 magnetite-rich skarns. All skarns magnetite are very pure (95.5 to 99.3 mol.% Fe$_3$O$_4$) and average concentrations represented by minor oxides are very low: 0.04 to 0.81 wt. % MnO, 0.01 to 0.63 wt. % MgO, 0.01 to 1.50 wt. % Al$_2$O$_3$ and 0.30 wt. % TiO$_2$. Siderophile (V, Cr) and chalcophile (Ni, Cu) are found in concentrations at or below the
limit of detection. These patterns are consistent with derivation of skarns by carbonate or calc-silicate replacement, and exclude their origin in other settings or by involvement exhalative or hydrogeneous components. Significant correlations at trace levels exist between ore-forming element pairs (e.g., Zn-Sn), various divalent pairs (e.g., Zn-Mn) as well as immobile couples (e.g., Al-Ti). Negatively correlated homovalent pairs (e.g., Mg-Fe$^{2+}$, Mn-Fe$^{2+}$, Al-V$^{3+}$) have the largest potential for reflecting the environmental conditions during magnetite crystallization, whereas the positively correlated Al-Ti pair reflects inheritance from the skarn precursor and element partitioning between coexisting phases. The Al$_2$O$_3$/TiO$_2$ ratios in magnetites (5.4-11.6 by weight) are substantially lower than those in the bulk magnetite-rich skarns (18.3-22.6), which is due to aluminum partitioning into garnet and/or clinopyroxene. Linear trend, the correlation between the Al-Ti and petrographic evidence of several occurrences show that skarns formed by replacement calcite or dolomite precursors, eventually siliciclastics rocks preserved as incomplete metasomatic relics.

Calcic-iron skarns in the Bohemian Massif are similar to typical metasomatic skarns of the world and their chemical composition excludes origin of metamorphosis volcano-sedimentary or exhalation precursors.