

Genetic aspects of hydrothermal mineralization in the Silesian Unit (Western Carpathians, Czech Republic): comparison of igneous and sedimentary minerogenetic environments

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The study area belongs to the Silesian Unit of the Outer Western Carpathian's Flysch Belt. The Silesian Unit is formed by dominating siliciclastic flysch marine sediments (Lower Cretaceous-to-Upper Oligocene), rare limestones (Upper Jurassic) and subordinate bodies of igneous rocks of teschenite association. The mafic and alkaline-to-subalkaline igneous rocks of the teschenite association are coincident with sedimentation of the Lower Cretaceous Těšín-Hradiště formation (Valanginian-Lower Aptian) and are widespread in the area between Hranice in Czech Republic and Bialsko-Biala in Poland. The magmatic rocks form hypoabyssal sills, dykes, pillow lavas and pyroclastics, and can be petrographically classified as teschenites, picrites, monchiquites and alkaline basalts. Igneous rocks are very variable in texture, mineral composition and chemistry, which is interpreted as a result of fractional crystallization, mixing of magmas of different origins, assimilation of sedimentary rocks and post-magmatic alterations. A typical feature of these rocks is the intense hydrothermal alteration, characterized by pervasive chloritization, serpentinization, carbonatization, silicification and zeolitization of primary magmatic mineral phases.

The recent mineralogical, fluid inclusion and stable isotope studies of amygdule and fracture mineralization in magmatic rocks revealed three stages of post-magmatic alteration which differ in both mineral association and formation conditions.

The Stage I mineralization is formed by titanite, aegirine-augite, annite, strontian apatite and analcime. Composition of this vein-type mineralization is typical for deuteric alteration which took place immediately after solidification of the host rock. Fluid inclusions indicate that the early phases (titanite and aegirine-augite) crystallized at high temperatures (390-510 °C)

from hypersaline NaCl-rich, CaCl₂-poor brines (47-57 mass% salts) at relatively low pressures (< 1 kbar). The origin of this mineralization is interpreted to be related to the residual fluids that remained after crystallization of silicic magma in shallow-seated setting.

The Stage II superimposed on previous stage is widespread in all rock types. It is formed by dominating coarse-grained carbonates (mainly calcite, locally also dolomite, ankerite, siderite, magnesite and/or strontianite), less occur chlorite (clinochlore-chamosite), sulphides (pyrite, marcasite, rarely sphalerite and millerite), celadonite, quartz, chalcedony and/or opal. The total range of homogenization temperatures of aqueous fluid inclusions is relatively wide (56 to 248 °C) and documents a significant temperature drop during the evolution of this mineralization. Most of the data are between 80 and 150 °C. The parent fluids are characterized by low salinity (0.2 to 3.7 eq mass% NaCl), Na-Cl or Na-Mg-Cl compositions, near-zero to highly positive fluid $\delta^{18}\text{O}$ values (between -1 and +17 ‰ SMOW), near-zero to highly negative fluid $\delta^{13}\text{C}$ values (between -17 and +1 ‰ PDB), and low content of strong REE-complexing ligands. The origin of fluids is interpreted to be predominantly in external sources, derived from surrounding sediments during diagenetic dewatering of clay minerals and/or warming-up caused by intrusions of magma.

The Stage III of mineralization is formed by fibrous calcite-dominating veinlets crosscutting both the older vein mineralization and host igneous rock. Mineralization found only at one location is composed of calcite and chlorite (clinochlore-chamosite). The homogenization temperatures of aqueous fluid inclusions present in calcite range between 83 and 155 °C. The fluids have generally low salinities (0.4 to 3.7 eq

mass% NaCl). The calculated fluid $\delta^{18}\text{O}$ values range between -1 and +6 ‰ SMOW and fluid $\delta^{13}\text{C}$ values around -12 ‰ PDB. This mineralization could have been possibly attributed to tectonic deformations connected with orogenic events in the Carpathian's realm during the Tertiary.

The hydrothermal assemblage filling joints in sedimentary flysch rocks is very simple, composed of carbonates (mainly calcite, locally also siderite); exceptionally also chlorite, dickite, quartz, pyrite and galena were recorded. Homogenization temperatures of fluid inclusions hosted by calcite exhibit relatively wide range (54 to 170 °C), however, most data are between 120 and 170 °C. The fluids have low salinities (0.4 to 2.6 eq mass% NaCl). It was not possible to determine fluid composition because no eutectic temperatures were measured. Both siderite and calcite are characterized by near-zero to positive calculated fluid $\delta^{18}\text{O}$ values (-1 to +12 ‰ SMOW) and negative fluid $\delta^{13}\text{C}$ values (-5 to -23 ‰ PDB). Chondrite-normalized REE patterns of calcite indicate crystallization under variable redox conditions and low content of strong REE-complexing ligands. The origin of the mineralization is evidently related to the diagenetic processes that took place in the host rock.

Data on fluid inclusions, stable isotopes and REE patterns of both carbonate-rich (i.e., Stage II and Stage III) hydrothermal mineralization hosted by igneous rocks and those of mineralizations present in sedimentary rocks are very similar. Our results suggest that in both environments operated fluids dominantly derived during dewatering of sedimentary sequences.

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