Metamorphic Pb-Ag mineralization at Albrunpass (Central Alps)

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Lead and silver occurrences are widespread in Triassic metasedimentary rocks of the central Alps. They are of interest as examples of mobilization and local enrichment of ore metals by regional-metamorphic fluids. The Binntal region in Switzerland hosts the Lengenbach deposit, which is famous for its exotic and partly unique Pb-As-rich sulfosalt minerals. At the southwestern termination of the same valley, near Albrunpass, an ancient mine produced Pb-Ag ore at a concentration ratio of 750:1. The mineralization lies exclusively in quartzite lenses within Triassic dolomite marbles enclosed by gneisses. Structural relationsips indicate emplacement of the ore during late stages of Alpine deformation and regional amphibolite facies metamorphism, in semi-ductile to brittle shear zones and late-metamorphic Alpine fissure veins.

The Pb mineralization consists of coarse-grained galena, with subordinate pyrite, fahlores (tennantite and tetrahedrite), chalcopyrite and accessory Zn-, Sn-, Ag-, Te- and REE-bearing minerals (notably stannite and bastnaesite group carbonates). Open space filling of fissures includes rhombohedral quartz, dolomite, adularia, galena, pyrite and rutile.

Free-grown quartz crystals host 3 different generations of fluid inclusions that have been studied by petrography, microthermometry and LA-ICPMS elemental analysis. A CO_2-rich, low-salinity (1-2 wt% $NaCl_{eq.}$) fluid with low metal contents represents the pre-ore stage fluid. Incursion of a high-salinity brine (~31 wt% $NaCl_{eq.}$), preserved in inclusions containing three daughter crystals at room temperature (halite, barite and probably sylvite), represents the input of the ore-forming fluid. It contains extremely high Ba, Pb and Mn concentrations. CO_2-rich fluids progressively diluted the ore-forming brine, thereby probably triggering PbS deposition in veins but also in microcracks together with brine. Base metal concentrations in the fluids gradually decrease with decreasing salinity. CO_2-rich fluid inclusions postdating the brines show variable salinities of 6 - 1 wt% $NaCl_{eq}$ and low base-metal content. The latest generation of fluid inclusions is a very low-salinity aqueous fluid trapped on secondary trails.

The ore metals at Albrunpass are interpreted to have precipitated by fluid mixing during late-metamorphic uplift and fissure formation. An exceptionally metal-rich aqueous brine probably originated from metamorphic equilibration with Triassic meta-evaporite units that may have contained dispersed Pb-Zn minerals of diagenetic origin. These brines mixed locally in fissures with ambient low-salinity CO_2-rich fluid of possible metamorphic basement origin, to generate a small but high-grade metamorphic ore deposit.

Some experimental constraints on major and trace element partitioning during partial melting of eclogite

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Isobaric partial melting experiments were performed to simulate partial melting of subducted oceanic crust. Experiments at 3.0 GPa yielded melts in equilibrium with garnet and aluminous clinopyroxene. Melt compositions show decreasing Si and alkalis, and increasing Ca, Mg and Ti contents with increasing temperatures. Experiments at 1200°C and 1300°C were rutile-saturated, whereas experiments at 1400°C contained no residual rutile. We argue that during the initial stages of subduction accessory rutile is likely to be stable in subsolidus eclogites of average MORB composition and that only large degrees of partial melting will eradicate rutile from an eclogitic source. At 3 GPa any eclogites with a bulk TiO_2 content of ≥1.5 wt.% rutile will produce rutile-saturated partial melts, except at very high degrees of melting. At higher pressures all bulk Ti may dissolve in clinopyroxene and garnet, leaving no accessory rutile.

Trace element partition coefficients for 24 trace elements between clinopyroxene, garnet and melt were determined by SIMS analysis of experimental run products. Partition coefficients for the rare earth elements agree well with previous studies and have been evaluated using the lattice strain model. Partitioning data for high field strength elements indicate complementary D_{Zr}/D_{Hf} for clinopyroxene and garnet. Partial melting of an eclogitic component of different modal compositions may, therefore, explain both sub-chondritic and super-chondritic Zr/Hf ratios. Super-chondritic Zr/Hf has recently been observed in some ocean island basalts (OIB) and this may be understood as further evidence for components of recycled oceanic crust in OIB.