Sulfosalt melts from low-grade metamorphic terrains: The case of the Monte Arsiccio mine (Tuscany, Italy)

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Sulfosalt melts formed during amphibolite/granulite facies metamorphism of pre-existing orebodies have been well documented (e.g., [1]). However, orebodies containing significant amounts of Low Melting Point Chalcophile Elements (LMCE - Ag, As, Bi, Hg, Se, Sb, Sn, Tl, and Te), could experience sulfosalt/sulfide melting at much lower metamorphic temperatures [2]. Up to date, low temperature LMCE sulfide melts have been documented, as inclusions in quartz, only at Lengenbach, Switzerland [3].

A new interesting case study was provided by the barite-pyrite-iron oxide ore deposit from Monte Arsiccio (Apuane Alps, Tuscany, Italy). The deposit originated during a Palaeozoic-Triassic sedimentary-exhalative metallogenic event and was successively metamorphosed and remobilized during the Alpine orogeny [4] under greenschist facies conditions (P = 0.6-0.8 GPa, T = 350-450°C; [5]).

Within these orebodies we discovered an exceptional Tl-Hg-As-Sb-(Ag, Cu)-Pb sulfosalt assemblage embedded in the barite-pyrite ore and in dolostones. Mineralogy is dominated by LMCE-bearing phases, mainly represented by Tl-Hg-Sb-As sulfosalts. The textural features of these assemblages (tiny veinlets pierced along grain boundaries, drop-like internal textures, low interfacial angles between sulfosalts and matrix mineral grains) is interpreted as the result of the mobilization of low-viscosity sulfosalt melts by percolation through the barite-pyrite crystal matrix, and veining in dolostones. Experimental studies (e.g., [6]) support our hypothesis, showing that thallium-bearing polymetallic sulfide systems have liquid phase fields down to very low temperatures (in the range 200-300°C). The physical (low viscosities and high density) and chemical (up to ~20% wt of Tl) characters of the inferred sulfosalt melts suggest that LMCE melt migration can be an effective mechanism of metal mobility in low-grade metamorphic terrains. The Tl-Hg-As-Sb-(Ag,Cu)-Pb sulfosalt assemblage from Monte Arsiccio likely documents the lowest temperature natural sulfosalt melt ever described.

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Magma emplacement and sulfide deposition after skarn formation at Campiglia Marittima, Tuscany

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Most economic skarn deposits are related to magmatic intrusions and a general correlation exists between the composition of igneous rocks and skarn ore type [1]. The Cu-Pb-Zn-Ag skarn deposit of Campiglia Marittima (Southern Tuscany, Italy) is the skarn deposit in which a mineralogical zoning of skarn bodies has been first described [2]. It has been considered as a classic example of exoskarn with an outward zoning sequence developed from a main axial dyke of mafic porphyry: magnetite ⇒ ilvaite ⇒ clinopyroxene ⇒ marble [3]. According to this model, the skarn deposit of Campiglia Marittima represents a key example for the understanding of the spatial and temporal evolution of a metasomatic system, from the local source of ore fluids (mafic porphyry) to the final products (skarn and sulfides).

The new field and laboratory data collected for Campiglia Marittima skarn deposit indicate that this classical model is too simplistic. Geological mapping of about 20 km of tunnels/shafts shows that: 1) mafic porphyry does not form a single axial dyke but small dykelets and pods that crosscut the skarn bodies and fill the skarn pockets; 2) the skarn bodies do not show symmetric, outward growing, mineralogical zoning, but they are formed by several metasomatic units displaying distinct mineral parageneses and growing patterns.

The later intrusion of mafic porphyry heated up the skarn bodies, inducing significant prograde back-reactions on skarn minerals: 1) ilvaite in direct contact with mafic porphyry was replaced by magnetite + hedenbergite; 2) pyrrothite, pyrite and chalcopyrite variably replaced ilvaite for several meters from the contacts; 3) hedenbergite crystals suffered overgrowth of Mg-rich rims.

Thus, a direct causality between magma emplacement, fluid release and skarn/ore formation, at a local scale, is not confirmed and must be searched at a larger, crustal scale. The magmatic source of skarn fluids is inferred to be a deeper, mafic intrusion. The shallow level of emplacement of such intrusion controlled the early exsolution of skarn fluids, and the later extraction of magmas that fed the mafic porphyry system, forming the main sulfide ores.

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