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Geological and chemical controls in ore shoot mineralization of polymetallic veins: insights from the five-elements Ni-Co-As-Ag-Bi hydrothermal veins of SW Sardinia

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Several studies on polymetallic hydrothermal veins of western Europe recently highlighted the role of physicochemical controls in determining and enhancing mineralizing processes in structurally defined, spatially limited environments (vein “ore shoots”). Host rocks have critical roles: a) the development and geometry of the structures and veins depend on their rheological features; b) they may act as sources of elements and c) regulate the type and kinetics of chemical reactions after fluid-rock interaction. An excellent example is provided in SW Sardinia by the five-elements (Ni-Co-As-Ag-Bi) veins of the Arburèse District. These late- to post-Variscan low-temperature veins are hosted in Ordovician-Silurian very low-grade metamorphic siliciclastic rocks outcropping between the Arbus granitoid (304±1 Ma) and the Mt. Linas granite (289±1 Ma). Ordovician host rocks mostly include sandstones and siltstones, while Silurian rocks are dominated by carbonaceous argillites (black shales). The distinct competence of these host rocks resulted in different geometries of spaces opened to fluid circulation, leading to the formation of orebodies with different shapes: large veins mainly occur in Ordovician sandstones and siltstones (e.g., Pira Inferida mine), while thinner, often anastomosed veins occur in Silurian black shales (e.g. Acqua Is Prunas mine). Vein formation is triggered by seismic cycles in faults at shallow crustal levels, as testified by widespread breccia and cockade textures. The ore shoots display complex mineral assemblages: native Bi; Ni-Co-Fe arsenides and antimonides (nickeline, breithauptite, rammelsbergite, safflorite, skutterudite, loellingite); Ni-Co-Fe sulfarsenides-sulfantimonides (gersdorffite, cobaltite, ullmannite, arsenopyrite); and Pb-Zn-Cu-Fe sulfides (galena, sphalerite, chalcopyrite, pyrite); Ag-Sb-As and Se sulfosalts. Carbonates (mainly siderite, minor ankerite, dolomite-calcite) and quartz are the main gangue minerals. Field, textural and analytical data support an overall rapid formation of ore minerals under multiple and distinct mineralizing pulses, starting with native elements and arsenides, followed by sulfarsenides and sulfides. Ore shoots must have formed in relatively restricted environments chemically marked by the abundant redox agents (carbonaceous matter, pyrite and, possibly, hydrocarbons) provided by Silurian black shales, which may have supplied sulfur and other elements (e.g., Se) for mineralization. Thus, differences in host rock geochemistry may explain local differences in ore shoots composition and paragenetic sequences. A further control at the district scale is represented by the repeated intersections of the five-elements vein system with earlier Mt. Linas granite-related Sn-As and W-Bi-

Te-Au veins, documented in several ore shoots of the district (Pira Inferida, Acqua is Prunas and Sa Menga mines). Such intersections formed preferred pathways for fluid circulation and wider spaces for mineral precipitation during ore-forming processes; moreover, main components of five-elements ores (e.g., As, Bi) appear to be inherited by remobilization from granite-related veins. In summary, ore shoot mineralization in the studied vein system may have been controlled by multiple factors (host structures; host rock rheology and composition; intersections with other vein systems) that may be assumed as key prospection guidelines for further mineral exploration in the area; until now this vein system has only been explored in its shallower parts, and it is possible that much of the ore shoots has yet to be discovered.