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Bi-minerals occurrence in various ore deposits of Southern Sardinia: a short review.

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Bismuth is recognized as a Critical Raw Material by the EU Commission and it is found in many ore deposits across the world. In Southwestern (SWS) and Southeastern (SES) Sardinia, Bi-minerals are commonly found in two main groups of ore deposit: 1) late Variscan granite-related orebodies including greisens, W-Mo(-Sn) HT hydrothermal veins, skarns and hornfelses; and 2) late- to post-Variscan five-element (Ni-Co-As-Bi-Ag) LT hydrothermal veins.

In the first group, greisens (Flumini Binu prospect, SWS) and HT hydrothermal W-Mo(-Sn) veins (Perd'e Pibera mine and Togoro prospect, SWS; Perda Majori-Bruncu Spangas prospects, SES) tipically host native Bi, bismuthinite and, subordinately, Pb-Ag-Bi-sulfosalts interstitial to molybdenite and/or scattered in the quartz-feldspar(-fluorite-topaz) gangue. Locally, maldonite (Au_2Bi), Bi-tellurides (hedleyite Bi_7Te_3, and Bi_2Te) and probable russellite (Bi_2WO_6) are abundant in wolframite-rich veins (Togoro prospect), associated with native Au. Small grains of native Bi have also been found in some poorly mineralized garnet-vesuvianite-epidote calc-silicate hornfelses (Domus De Maria, SWS). Besides native Bi and bismuthinite, skarn orebodies frequently host wider assemblages consisting of Bi-Pb-Ag-Cu-sulfosalts intergrowths, once again associated with wolframates (scheelite at Monte Tamara prospect and Sa Marchesa mine, SWS) and molybdenite (Monte Tamara, Sa Marchesa and Morettu prospect, SWS). As a reference, the Monte Tamara assemblage includes "phase 88.6" ($Cu_{0.33}Pb_{0.33}Bi_{7.67}S_{12}$), pekoite ($PbCuBi_{11}S_{16}Se_2$), salzburgite-paarite ($Cu_{1.58\text{-}1.67}Fe^{2+}_{0.03\text{-}0.01}Pb_{1.65\text{-}1.72}Bi_{6.38\text{-}6.3}S_{12\text{-}12.06}$), gustavite ($PbAgBi_3S_6$) xilingolite-lillianite ($Pb_3Bi_2S_6$), cosalite ($Pb_2Bi_2S_6$), berryite ($Cu_3Ag_2Pb_3Bi_7S_{16}$), ourayite ($Pb_4Ag_3Bi_5S_{13}$) and cupropavonite ($Cu_{0.9}Ag_{0.5}Pb_{0.6}Bi_{2.5}S_5$), identified by means of EPMA analyses. Moreover, since high Bi(-Ag-Te) contents have been detected in sulfides (sphalerite, galena, arsenopyrite), micro-inclusions of -sulfosalts and/or -tellurides may also occur. In the same area, wittichenite ($(Bi,Cu)_2S_3$) and hammariite ($Pb_2Cu_2Bi_4S_9$) have been previously identified, while schapbachite ($AgBiS_2$) has been reported at the Sa Marchesa mine.
The second group of Bi-bearing orebodies includes the five-element veins of the Arburèse district (Pira Inferìda, Acqua Is Prunas and Sa Menga mines, SWS), where native Bi and bismuthinite tipically occur at the core of Ni-Co arsenides-sulfarsenides (e.g. nickeline and gersdorffite-cobaltite) concentric growths.

Therefore, the strong affinity of bismuth for granite-related W-Mo(-Sn) deposits of Southern

Sardinia indicates that the late-Variscan (Early Permian) granites represent its main metallogenic source. However, the formation of such diverse Bi-minerals assemblages is seemingly controlled by local-scale conditions. In skarn ores, the Bi-Pb-Ag-Cu-sulfosalts intergrowths formed during the sulfide stages, apparently after the interaction between primary Bi-phases and Pb-Ag-Cu-bearing hydrothermal fluids and under oscillatory variations of metals availability and stability. Conversely, in W-Mo(-Sn) hydrothermal veins and greisens, where sulfides are apparently more scarce, the array of Bi-phases is usually more limited. Furthermore, field and analytical data point towards a selective remobilization of bismuth from the primary native and -tellurides assemblage of HT wolframite-quartz veins (Togoro, SWS) by late cross-cutting LT five-element veins, suggesting that multiple, spaced over time hydrothermal-veining events occurred in the same area.
In conclusion, bismuth and related mineral phases could serve as important markers, providing useful qualitative indications regarding the source of metals, the ore-forming processes and the relationships between different ore deposits at the district-scale.