



Low-temperature, hydrothermal base and precious metal deposits hosted by volcanic-sedimentary sequences of the Camaquã basin, southernmost Brazil

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This paper reviews the most important Au and base-metal ores hosted by Neoproterozoic volcanic–sedimentary sequences in the Camaquã basin, mined for half a century in southern Brazil (Camaquã Cu-Au; Santa Maria Cu-Pb-Zn and Cerro dos Martins Cu deposits). All deposits contain ore sulfides that are mainly fracture-controlled and also disseminated in the matrix of siliciclastic and volcanic rocks. The Camaquã deposits consist of NW veins, stockworks and disseminated ores enclosed in conglomerates and sandstones. These contain chalcopyrite, bornite, chalcocite, pyrite, gold and silver accompanied by chlorite, white mica, quartz, albite, carbonate and later barite and hematite. The ores of the Santa Maria deposit are disseminated in arenites and conglomerates or occur as massive lodes crosscutting the stratigraphy. Sphalerite and galena intergrowths are the dominant texture in the ores while chalcopyrite and chalcocite are minor accompanied by carbonate, chlorite, adularia and barite. The ore lodes of the Cerro dos Martins consist of a set of Cu-sulfide NW-trending veins and disseminations within the volcanic-sedimentary sequence. Chalcocite and bornite are the main ore minerals with minor chalcopyrite, galena and sphalerite, whereas carbonates, barite, quartz and hematite are the gangue. The volcanic host rocks show an alkaline affinity and the age of mafic-related dyke is $550 \pm \text{Ma}$. Geothermometry of the three deposits show deposition temperatures within the hydrothermal field (maximum of ca. 215 to 300 °C). Sulfur isotope $\delta^{34}\text{S}$ results of sulfides show homogeneous composition, with values in the range of -1.8 to +0.6‰ (Camaquã); -7.1 to +1.1‰ (Santa Maria) and -6.2 to +0.9‰ (Cerro dos Martins) which indicates a magmatic origin for the sulphur of the deposits. The negative values for Santa Maria indicates a minor contribution of sedimentary reduced-sulfur derived from remobilization of diagenetic pyrites. Oxides like hematite in the mineral paragenesis of Cerro dos Martins suggest oxidizing conditions, which would shift the original magmatic sulfur isotopic compositions to negative values. The $\delta^{13}\text{C}_{\text{PDB}}$ of calcite from gangue and cement of Camaquã (-2.47), Santa Maria (-0.43 to -2.85) and Cerro dos Martins (-1.90 to -4.45‰) are interpreted as originated from mixed sources – magmatic fluids contaminated by basement marbles from Vacacai unit. Sr-isotope composition from least radiogenic sulfides of Camaquã (0.7087) show values very close to the gangue carbonate (0.7082) that overlap the values of Cerro dos Martins carbonates (0.7068 to 0.7087) which are consistent with an origin by mixing of hydrothermal fluid and remobilizations from basement marbles. The Pb-isotope results for sulfides from three deposits form a linear array. The least radiogenic isotopic compositions from these deposits overlap the Pb-isotopic composition of Cu-sulfide ores from Crespos deposit which is hosted by rhyolites from Acampamento Velho Formation (ca. 545 Ma age). The sulfide Pb isotope composition of ores would be derived from mixing between magmatic fluid and basement metamorphic /sedimentary rocks. The age of mineralization from previous work of 535 to 474 Ma (K-Ar in mica/ilite from gangue in Camaquã) are interpreted as the minimum age of deposits. Thus, mineralization is coeval and related to a magmatic event around ca 545 Ma (alkaline magmatic events).