

## **Ore textures and lead isotope compositions of the Zhaxikang Sb-Pb-Zn-Ag deposit in southern Tibet: Implications for ore formation**

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Many Au, Sb, Sb–Au, Pb–Zn, and Sb–Pb–Zn–Ag vein deposits are present throughout the North Himalaya in southern Tibet, China. The largest Sb–Pb–Zn–Ag deposit at Zhaxikang (18 Mt at 0.6 wt% Sb, 2.0 wt% Pb, 3.5 wt% Zn, and 78 g/t Ag) is studied here to constrain the nature of ore formation. Orebodies of the Zhaxikang deposit are hosted within nearly N–S trending faults which crosscut rocks of the Early–Middle Jurassic Ridang Formation consisting of shale interbedded with sandstone and limestone deposited on a passive continental margin.

Two pulses of mineralization can be recognized at Zhaxikang. The early pulse of mineralization includes two stages of mineralization that produced fine-grained Mn-Fe carbonate, brown sphalerite, pyrite, and arsenopyrite (stage 1) and coarse-grained Fe-Mn carbonate and brown or black sphalerite and galena (stage 2). Stage 1 sulfides together show well-defined micrometer-scale laminae in Mn-Fe carbonate or cemented Mn-Fe carbonate which looks like colloform layers or crustiform texture, indicative of rapid coprecipitation of sulfides and Mn-Fe carbonate. Distinctive features of stage 2 mineralization are the coarse-grained texture, significant replacement of Mn-Fe carbonate by sphalerite, an increasing amount of galena and sphalerite, and sphalerite with relatively lower Mn content compared with stage 1 sphalerite. These imply slow deposition of minerals and more oxidized, acidic, and metal-rich fluids during stage 2 than stage 1. Lead isotopes of sulfides indicate that metal sources for stage 2 mineralization are derived from more radiogenic Himalayan basement rocks and less radiogenic rocks such as those of the Ridang Formation.

The onset of later stages of mineralization was marked by the formation of quartz veins that commonly contain sulfosalts and stibnite. These veins generally crosscut pre-existing Pb-Zn sulfide-bearing Mn-Fe carbonate veins. Four stages of mineralization can be recognized. Stage 3 is characterized by remobilization and dissolution of sphalerite and galena and deposition of quartz. Ore fluids during this stage likely have high temperature and salinity, and are relatively more oxidized as evidenced from lower content of Mn in stage 3 sphalerite, which would facilitate dissolution of sulfides. Stage 4 is marked by replacement of pre-existing sulfides and precipitation of Sb-Pb sulfosalts in quartz veins. Remobilized Pb–Zn sulfides of stage 3 and newly formed Sb–Pb sulfosalts of stage 4 have more radiogenic lead isotope ratios than primary Pb–Zn sulfides of stage 2. This can be reconciled if Pb from the pre-existing sulfides is reworked and more radiogenic Pb is introduced from the overprinting fluids that probably leached lead from the Himalayan basement. Stage 5 consists of an assemblage of quartz, stibnite, and cinnabar, which generally occurs in veins at shallow levels and is spatially associated with siliceous sinter. Stibnite samples show much less radiogenic Pb isotopes than galena and Sb–Pb sulfosalts, indicating that their lead isotopes are likely not influenced by pre-existing minerals and ore fluids leached lead mainly from the Early Cretaceous diabase. Stage 6, which represents the youngest mineralization, is characterized by an assemblage of quartz and calcite that cuts sulfides of all previous stages.