

Precipitation of Ge-Cu-S Nanominerals as a Mechanism for Ge Accumulation in Zn-Pb Carbonate-hosted Deposits: Evidence From Prairie Creek Deposit, Canada

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Germanium is an essential element driving advances in electronics, fiber optics and photovoltaics. Growing demand has raised concerns about supply security, leading to its classification as a critical mineral. Ge is primarily recovered as a by-product of Zn production, with particularly high concentrations in Zn-Pb carbonate-hosted deposits. However, the mechanisms controlling Ge enrichment in these deposits remain debated. Here, we investigate the Ge-bearing Zn-Pb-Ag Prairie Creek deposit across multiple scales to elucidate the processes responsible for Ge accumulation.

The Prairie Creek deposit, located in the Mackenzie Mountains of northwestern Canada, exhibits two main styles of mineralization: 1) stratabound replacive massive sulfides (SMS) and 2) quartz-carbonate veins (MQV). Economically significant Ge concentrations (up to 300 ppm) occur exclusively within the SMS, which is hosted in fine-grained dolostones. The SMS ore body contains two generations of sphalerite (Sp I and Sp II). LA-ICP-MS analyses show that Sp I is enriched in Ge and Cu (up to 2600 ppm and 4275 ppm, respectively), whereas Sp II contains much lower concentrations (< 50 ppm Ge; < 200 ppm Cu). Trace-element mapping reveals distinct spatial distributions. In Sp I, Ge displays oscillatory zoning and is correlated with Cu, Ag, and Tl, suggesting apparent coupled substitution mechanisms. In contrast, nanoscale analyses (APT and TEM) demonstrate that Ge and Cu in Sp I predominantly occur as discrete nano-sized Cu-Fe-Ge sulfides (5-80 nm), rather than as lattice-bound components. Furthermore, petrographic and EBSD analyses show no evidence of metamorphism or dynamic recrystallization affecting Sp I, implying that trace-element distributions were not modified by post-depositional remobilization.

These observations indicate that Ge enrichment in the Prairie Creek deposit results from primary co-precipitation of nano-mineral inclusions formed through chemical fluctuations in the boundary layer during sphalerite growth, rather than by substitution into the sphalerite lattice or post-depositional remobilization.