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From Co-rich sulfarsenides to Ni-rich sulfides: Co-Ni hosts in the Eloise Iron-sulfide-copper-gold (ISCG) deposit, Queensland, Australia

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Iron-sulfide-copper-gold deposits (ISCG) are a sulfide-dominant variety of IOCG systems which often have by-product grades of other critical metals such as Co and Ni. The Eloise deposit in the Cloncurry district, Queensland, Australia is a lode-style ISCG deposit where Co-rich zones were identified and studied. Samples were collected from four different lodes (Eloise Deeps, Chloe, Macy and Middle West) across the deposit and characterised using reflected light petrography, EPMA and LA-ICP-MS analysis.

Detailed petrography reveals textural relationships and indicate the following paragenetic sequence: an early oxide stage (magnetite), followed by sulfarsenides (glaucodot, arsenopyrite, cobaltite) and finally an extensive Fe-Cu-Ni sulfide stage (pyrite, pyrrhotite, pentlandite, chalcopyrite). Cobalt-rich phases, including glaucodot, cobaltite and Co-rich arsenopyrite are concentrated in the deeper and southernmost part of the system (Eloise Deeps). Major and trace element data reveal a systematic distribution of Co and Ni between these mineral groups. Cobalt occurs as cobaltite $(Ni_{0.08}Co_{0.82}Fe_{0.10})As_{0.95}S_{1.02}$ and glaucodot $(Ni_{0.19}Co_{0.60}Fe_{0.22}Cu_{0.02}As_{0.93}S_{1.05})$, whereas Ni is mainly hosted in pentlandite $(Ni_{3.63}Co_{1.65}Fe_{3.65})S_{8.}$

Based on EPMA stoichiometry calculations and the As-Ni-Fe phase diagram, early arsenopyrite and glaucodot yield geothermometry temperature estimates of ~550 °C, whereas late arsenopyrite and Co-Ni-rich cobaltite formed around ~370 °C. Early arsenopyrite is Co-Ni enriched whereas later arsenopyrite approaches a more stoichiometric FeAsS composition. As mineralisation transitions from the sulfarsenide to Fe-Cu-Ni sulfide stage, Co and Ni are remobilised; Ni partitions to pentlandite, and Co to pyrite and pentlandite. This redistribution led to the formation of a more stoichiometric arsenopyrite and cobaltite with Co dominant composition.

These observations indicate that arsenic activity controls Co distribution during sulfide mineralization. The relative activity As/(As+S) changed from ~0.469 to ~0.477 during the redistribution phase which promoted Co enrichment in the sulfarsenide stage. Reduced As availability during sulfide mineralisation favoured Ni incorporation into sulfides such as pentlandite, which caused a shift from Co- to Ni-rich sulfides. Our dataset from the Eloise ISCG deposit show that mineral stability, arsenic activity, temperature, and host rock interaction play a key role in enriching ISCG deposits in Co, Ni and other critical metals.