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Metamorphic Upgrading of Cobalt in a Volcanogenic Massive Sulfide Deposit

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Intra-deposit remobilization of sulfides and their contained metals is well documented in many deformed and metamorphosed massive sulfide deposits. Significantly fewer examples are known where additional metals were added during tectonism. We use a combination of in situ microstructural mapping by electron backscatter diffraction (EBSD) and compositional mapping by laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) to show that additional cobalt was added to the Windy Craggy Cu-Co-(Au-Ag) volcanogenic massive sulfide deposit, Canada, during deformation and greenschist-facies metamorphism.

At Windy Craggy, cobalt occurs in primary hydrothermal pyrite and pyrrhotite, as well as local metamorphic pyrite overgrowths and syn-deformational cobaltite. Cobalt substitutes directly for iron in pyrite and pyrrhotite, and is thus tightly bound in the crystal lattice. Extensive mechanical remobilization of hydrothermal pyrrhotite (by dislocation creep and dynamic recrystallization) did not affect its cobalt contents, whereas pyrite incorporated additional cobalt during local dynamic recrystallization. As such, no cobalt was lost from major cobalt-bearing phases within the deposit during tectonism, and the additional cobalt required to form the Co-rich metamorphic pyrite overgrowths and cobaltite must come from a source external to the deposit. We propose that the mafic (and possibly ultramafic) rocks that host the deposit provided the cobalt. During formation of the deposit, hot (~350-380°C) hydrothermal fluids leached cobalt from mafic ± ultramafic rocks in the underlying upflow zone, providing the cobalt that was incorporated into the original hydrothermal pyrite and pyrrhotite. During subsequent deformation and metamorphism, which occurred at similar temperatures (~370°C), metamorphic fluids extracted cobalt from a broader region of previously unaltered mafic ± ultramafic rocks. These fluids were channeled along localized faults, and where these structures intersected the Windy Craggy deposit, additional cobalt was added in the form of the metamorphic pyrite overgrowths and discrete cobaltite grains.