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The role of mineral nanoparticles at a fluid-magnetite interface: Implications for trace-element uptake in hydrothermal systems

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ABSTRACT

The migrating fluid-mineral interface provides an opportunity for the uptake of trace elements as solid solutions in the newly formed crystal lattice during the non-equilibrium growth of the crystal. However, mineral nanoparticles could precipitate directly from the interfacial fluid when it evolves to a supersaturated situation. To better understand the role of mineral nanoparticles in this scenario, this study focuses on a well-documented magnetite with oscillatory zoning from a skarn deposit by using high-resolution transmission electron microscopy (TEM). Our results show that the Al concentration in magnetite measured on a micrometer-scale is caused by three different effects: Al solid solution, Al-rich nanometer-sized lamellae, and zinc spinel nanoparticles in the host magnetite. Here, we propose a genetic relationship among the three different phases mentioned above. At first, a continuous increase of the Al concentration in the interfacial fluid can be incorporated into the crystal lattice of magnetite forming a solid solution. During cooling in a later stage, aluminum in magnetite is oversaturated and exsolution of hercynite (Al-rich lamellae) occurs from the host magnetite. If the Al concentration at the fluid-magnetite interface still increases during further growth of magnetite, the substitution of Fe by Al has gradually reached saturation so that aluminum cannot be incorporated in the magnetite crystal structure any longer. Using the magnetite lattice as a template, nucleation of abundant zinc spinel nanoparticles occurs. This will, in turn, lead to a gradual depletion of Al concentration in the interfacial fluid until the available ions for zinc spinel nucleation and growth have been used up. As a result, the migrating fluid-magnetite interface will enrich the Al concentration in the interfacial fluid until the available ion concentration is sufficient for nucleation of zinc spinel phase again. The fluid-mineral interface in this mechanism has been repeatedly utilized during crystal growth, providing an efficient way for the uptake of trace element from a related undersaturated bulk fluid.

Keywords: Fluid-mineral interface, mineral nanoparticle, hydrothermal magnetite, uptake of trace element