Is solid-state diffusion slower than dissolution-reprecipitation during low temperature mineral-fluid interactions?

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The formation and alteration of mineral assemblages often involve mineral replacement reactions. Solid-state diffusion received more attention in the early years as the responsible mechanism, while recent studies acknowledged the interface-coupled dissolution-reprecipitation (ICDP) mechanism. In the presence of a fluid phase and at low temperatures (e.g., <300 °C), numerous experiments demonstrated the dominating role of ICDP in mineral replacement processes. This is expected because in most minerals, solid-state diffusion is too slow at low temperatures.

However, our experiments on the hydrothermal replacement of endmember bornite (Cu_5FeS_4) by copper sulfides demonstrated that the rate of solid-state diffusion is comparable to the rate of dissolution-reprecipitation processes, at 160-200 °C. The experiments initially produced chalcopyrite lamellae rapidly. The lamellae were homogeneously distributed in bornite and each lamella was enveloped by digenite. The lamellae were formed by solid-state diffusion since there is no evidence for fluid entering nonporous bornite during lamellae formation. We suggest that the solid-state lamellae exsolution was induced by the fluids surrounding the mineral grains. This is because in the absence of fluid, no lamellae were formed, and because both the exsolution rate and lamellae size were sensitive to the composition of the fluids. In parallel to lamella exsolution, ICDP reactions proceeded from the surface to the interior of the grains or along the fractures, replacing chalcopyrite by digenite, and digenite by covellite and/or chalcocite, depending on the experimental conditions.

This study highlights that in some cases hydrothermal fluids can initiate and control solid-state diffusion processes, i.e., exsolution, and that mineral replacement can be a result of solid-state diffusion and dissolution-precipitation operating at the same time, even at low temperatures.