

Towards a quantified description of mineral precipitation rates

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One of the great challenges in the accurate quantitative modelling of the rate and extent of water-rock interaction during natural and industrial processes is defining the precipitation rates of the major rock forming minerals. Whereas minerals readily dissolve in undersaturated aqueous fluids, numerous major rock forming minerals fail to precipitate even in strongly supersaturated fluids. This is particularly evident at lower temperatures. For example, quartz and magnesite rarely, if ever, precipitate at temperatures less than ~80 °C. At these conditions metastable phases of similar compositions dominate. The difference between the behaviors of dissolution and precipitation stem from their mechanisms. Dissolution creates its own reactive sites, whereas precipitation requires both the creation of new reactive sites and the growth of these sites.

This presentation brings together a large number of distinct observations that illuminate the behavior of mineral precipitation rates as a function of temperature, mineral composition and structure. Such observations include:

- The consistency between isotopic exchange of metals at mineral surfaces dissolution/precipitation rates on a number of simple mineral water systems at ambient temperature
- The variation of mineral precipitation rates measured as a function of chemical affinity (e.g., the degree of disequilibrium of the mineral-water system).
- The thermodynamics of metastable mineral precipitation versus the lowest formation temperature of their more stable counterparts.
- The consistency measured mineral dissolution rates at temperatures <300 °C with high temperature oxygen exchange rates.

These observations compel a unified description of mineral precipitation rates that combines an equation describing the nucleation of reactive sites on mineral surfaces proportional to the square of the chemical driving force of the precipitation reaction and an equation describing growth at these reactive sites proportional to this driving force. This latter equation can be quantified using corresponding mineral dissolution rates taking account transition state theory. As the activation energy for the former process is larger, slow nucleation rates dominate at lower temperature but growth dominates at higher temperature. The incorporation of this combined description of mineral