

Nanoscale imaging of toxic element sequestration: coupled dissolution and precipitation reactions at the mineral-fluid interface

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123

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Understanding how minerals react in the presence of aqueous fluids is essential to track the evolution of rocks in the crust of the Earth as well as estimating the composition of the fluid and its origin. In undersaturated solutions minerals will tend to dissolve. However if the fluid, directly at the mineral surface, becomes supersaturated with respect to a new phase due to dissolution, precipitation may also take place from within a mineral-fluid boundary layer, whose composition may differ greatly from the bulk fluid. Such interface-coupled dissolution-precipitation reactions are surprisingly common in the Earth and lead to element mobilization as well as potential sequestration. Different conditions, such as, fluid composition, pH, redox, t, T and p, all influence dissolution, nucleation and growth processes and whether or not one mineral can be replaced by another mineral. The concomitant generation of porosity and its subsequent evolution governs element mobility in the Earth. Atomic force microscopy (AFM) has enabled us to observe these reactions *in situ* at the nanoscale and thereby to elucidate the mechanisms of these coupled processes. Carbonate, sulfate and phosphate minerals have been imaged during *in situ* reactions to observe the sequestration of toxic elements such as As, Se, Sb and high concentrations of P. By precipitating these ionic species in a new more stable product mineral, they are effectively removed from the environment. This can also be applied to CO₂ sequestration and to other systems whenever minerals are in contact with aqueous fluids, such as in biomineralization, scale formation in industrial systems, as well as in novel synthesis methods in material science. Such nanoscale studies will ultimately enable us to predict potential reactions that could be effective for environmental remediation applications.