Growth of complex mineral surfaces with and without fluid flow

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Precipitation of mineral aggregates near the Earth's surface or in subsurface fractures or cavities often produce complex microstructures and surface morphologies. Here we demonstrate how a simple surface normal growth (SNG) process may produce microstructures and surface morphologies very similar to what is observed in some natural carbonate surfaces. A simple SNG model may be fit to observed surfaces to provide information, not only about growth history, but also about the frequency and spatial distribution of nucleation events during growth. The SNG model can be extended to systems where the symmetry of precipitation is broken by fluid flow. A simple modification of the SNG model where the local growth rate depends on the distance from some fluid source and the local slope or fluid flow rate, produce growth structures with many similarities to natural travertine deposits.

We also present a more realistic model for the growth of calcite from supersaturated aqueous solutions under laminar, open-channel flow conditions that couples solution chemistry, precipitation at solution/calcite interfaces, hydrodynamics, diffusion and degassing. The model output is compared with experimental results obtained using an oversaturated calcite solution produced by mixing $CaCl_2$ and Na_2CO_3. The precipitation rate is observed to increase when the supersaturated solution flows over an obstruction, leading to a growth instability that causes the formation of terraces. At relatively high flow rates, the most important mechanism for this behaviour is hydrodynamic advection of dissolved species either towards or away from the calcite surface, depending on location relative to the obstruction, which deforms the concentration gradients.

At lower flow rates, steepening of diffusion gradients around protrusions becomes important. Enhanced degassing over the obstruction due to shallowing and pressure drop is not important on small scales. Diffusion controlled transport close to the calcite surface can lead to a fingering-type growth instability, which generates porous textures. Our results are consistent with existing diffusive boundary layer theory, but for flow over non-smooth surfaces, simple calcite precipitation models that include empirical correlations between fluid flow rate and calcite precipitation rate are inaccurate.

In situ precipitation of arsenic and heavy metals in contaminated soils by microbiological sulfate reduction

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The effect of *in situ* metal precipitation based on microbiological sulfate reduction was investigated using the indigenous bacteria isolated from the arsenic and heavy metals-contaminated soils from the Songcheon Au-Ag mine site. Batch experiments were conducted to get the information on the optimum concentration range of carbon source and sulfate to achieve microbiological sulfate reduction. Column experiments were performed to investigate the microbiological sulfate reduction process in a more realistic aquifer system. Special attention was given to the sensitivity of the sulfate reducing system during the injection time of oxygen-rich solution. The soil has low pH value of 2.99 and very low nitrogen and carbon concentrations. Total metal concentrations were determined as As 1,311 mg/kg, Cu 146 mg/kg, and Pb 294 mg/kg by aqua regia digestion. Except for control setups, sulfate concentration and redox potential dropped rapidly in the batch tests. There was also a substantial metal removal rate for bacterial setups. This demonstrates a strong promotion of sulfate reducing activities. Batch experiments revealed an optimal carbon source and sulfate concentration range of 0.2 – 0.5 % (w/v) and 100 – 200 mg/L, respectively. In column experiments, precipitation of metal sulfides was induced biologically as well as chemically by adding Na_2S. In both systems, up to >99% of initial arsenic and heavy metal concentration was removed. After the injection of oxygen-rich solution, the microbiological sulfate reduction system showed the continuation of metal stabilization for at least one month suggesting the insensitivity of the biological system to the altered environment. Black amorphous iron sulfide precipitates were formed additionally in both batch and column setups. It is important that they have a potential as a buffer to prevent the system from being reoxidized by the unexpected supplies of oxygen.