Nanoscale characterization of the 'critical zone' of naturally weathered feldspars by FIB and TEM

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Introduction: exploring the critcal zone at the nanoscale

Information on weathering mechanisms is recorded by grain surface topography and the microstructure and chemical composition of the grain immediately beneath the surface and any overlying reaction products. Here we describe a method that enables investigation of this ~1-2 μm thick 'critical zone' in unprecedented detail. We have studied naturally weathered alkali feldspar grains that were hand-picked from ~1 kyr old soils formed on river terraces in Glen Feshie (NE Scotland) and ~10 kyr old soils overlying the Shap Granite (NW England). A focused Ga^+ ion beam (FIB) microscope was used to cut ~100 nm thick cross-sections from outer surfaces of these grains for high resolution imaging and chemical analysis by transmission electron microscopy (TEM).

Topography & crystallinity of feldspar surfaces

Diffraction-contrast images of cross-sections of the Shap grains show that the size, shape and location of nanoscale etch pits is controlled by the magnitude and distribution of elastic strain associated with exsolution microtextures. These feldspars are completely crystalline up to the weathered grain surface. If amorphous layers, comparable to those formed during laboratory silicate dissolution, are present they must be <~2-3 nm thick. Surfaces of the Glen Feshie grains are less pitted and are overlain by silicate weathering products that are typically amorphous but contain smectite crystallites.

Evidence for microbial weathering

We have also investigated the role of microbes in weathering by cross-sectioning fungal and algal remains on grain surfaces. The Ga^+ ion beam destroys biological details, but the microbe-feldspar interface is preserved intact. There is little evidence for biological enhancement of feldspar weathering, although the close association of fungal hyphae with smectite in the Glen Feshie samples indicates that microbes may assist in crystallization of weathering products.

Summary: future applications of the FIB-TEM technique

The FIB-TEM technique has tremendous promise for revealing the nanoscale properties of weathering that occur at mineral surfaces.