

## **Morphological approach to understanding mineral alteration and nanoparticle formation under alkaline conditions using granitic rock thin sections**

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### **ABSTRACT**

The cement components in deep geological disposal facilities (DGFs) for spent nuclear fuel can increase groundwater pH, potentially altering minerals within natural barriers. Mineral dissolution (biotite, quartz, plagioclase, chlorite, and K-feldspar) and secondary-phase precipitation were investigated to provide a visually integrated understanding of the multifaceted processes. This study was based on the morphological features of granitic rock thin sections exposed to alkaline aqueous solutions (initial pH: pH<sub>0</sub> 9 and 13) using atomic force microscopy (AFM), micro-X-ray fluorescence, and scanning electron microscopy/energy-dispersive X-ray spectroscopy. Batch kinetic-alteration tests were conducted for durations from 4 h to 20 days using solutions with different initial pH values (pH<sub>0</sub>). The minerals exhibited more pronounced changes in surface roughness and Si release at pH<sub>0</sub> 13 than at pH<sub>0</sub> 9. Furthermore, precipitates were more abundant on the mineral surfaces at pH<sub>0</sub> 9 than at pH<sub>0</sub> 13. Fe (oxy)hydroxides and Al (oxy)hydroxides prevailed as precipitates at pH<sub>0</sub> 9, whereas Ca (oxy)hydroxides dominated at pH<sub>0</sub> 13 (pH ≥ 12.8). These findings indicate that aqueous solutions were significantly involved in the formation of the secondary-phase precipitates. Interestingly, secondary phases precipitated not only on the surface of the mineral (i.e., biotite), providing constituent ions, but also on the surfaces of adjacent minerals (i.e., quartz and plagioclase). Moreover, the possibility of a multistep process involving Al precursors for nucleation of gibbsite precipitates on the surface of K-feldspar at pH<sub>0</sub> 9 and colloidal particle formation through surface modification, often overlooked in mineral research, was identified via AFM image analysis. This methodological approach using rock thin sections can provide new visual insights regarding the dissolution–precipitation processes, including nucleation reactions, under conditions closely resembling the expected environmental settings within DGFs.

**Keywords:** Morphological feature, granitic rock, alteration, precipitates, nanoparticles, atomic force microscope