

## Acid-sulfate weathering pathways at Cerro Negro, Nicaragua

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### Acid-sulfate weathering on Mars and Earth

Observations from Mars orbiters and landers have identified numerous deposits of sulfate-rich bedrock in diverse geological settings [1, 2, 3]. One proposed mechanism for formation of the deposits is the high temperature, low pH alteration of Martian basalts by sulfur-rich vapors early in the planet's history. Cerro Negro, Nicaragua is an active volcanic system with the aforementioned conditions and has lithology similar to unaltered Martian basalt and SNC meteorites. These characteristics make it an ideal analog for early Mars.

### Acid-sulfate weathering experiments

We are completing a comprehensive set of experiments on the individual mineral components of Cerro Negro basalt to elucidate the geochemical pathways and weathering rates in this environment. The basalt is phenocryst-rich and comprised of Ca-rich plagioclase, augite, and olivine within a glassy matrix. In a series of experiments, we have examined the reactions of bytownite, augite, forsterite, quartz, and glass with 1M H<sub>2</sub>SO<sub>4</sub> at 65°C. The fluid to rock ratio was about 4:1 and they ran for 3 to 40 days.

Analysis with x-ray diffraction and scanning electron microscopy (with energy dispersive spectroscopy) indicates the formation of abundant sulfate minerals, even in the shortest timestep. Alteration of bytownite yielded mainly Al- and Ca-sulfates, whereas augite yielded abundant Ca- and Mg-sulfates (in multiple crystalline forms). While forsterite analysis indicates Mg-sulfate formation, generally as a surface coating, it lacked clearly defined crystal structures. Quartz shows little to no alteration in all of the timesteps. Experiments with glass are just underway. Understanding these weathering reactions and rates under high T, low pH conditions will help constrain the early Mars environment.

[1] Gendrin *et al.* (2005) *Science* **307**, 1587–1591.

[2] Murchie *et al.* (2009) *JGR* **114**, E00D07. [3] Squyres *et al.* (2007) *Science* **316**, 738–742.

## Going deep: Elemental distribution, speciation and redox states in a marine ferromanganese nodule

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Deep-sea ferromanganese nodules are of interest to environmental geochemists for several reasons. Although they grow very slowly (mm/Ma) and have spent megayears immersed in water, they retain a non-equilibrium nanocrystalline structure. They show intricately-detailed spatial variation of composition, which potentially encodes information about ocean chemistry over tens of Ma. Their nanocrystalline structure makes them 'sponges' for trace element sorption.

Using a hard X-ray microprobe at the Advanced Light Source (Beamline 10.3.2), we have examined a nodule from the South Pacific Gyre, an area of low primary productivity and therefore slow nodule growth. We have performed micro X-ray fluorescence mapping to see the distributions of major (Fe, Mn), minor (Ni, Cu, Co) and trace (Ti, V, Ce, Zn) elements, as well as micro X-ray absorption spectroscopy for speciation and redox-state measurement. Micro X-ray diffraction was used to characterize the nanophase host materials. These studies have been carried out in two areas at different distances from the surface of the nodule and hence presumably different ages.

The distributions of all elements may be decomposed into sums of three 'patterns', as if every point in the examined area consisted of a mixture of just three materials, each containing different proportions of the studied elements.

The redox-sensitive elements Co, V and Ce show variable oxidation states instead of being fully-oxidized as one might expect from the presence of the strong oxidizer MnO<sub>2</sub>. There is evidence for the presence of phosphate, which may have acted to keep the metals from complete oxidation.