Metals and microbes: imaging organic matter-mineral relationships at high resolution with STXM/NanoSIMS

JENNIFER PETT-RIDGE[1*], MARCO KEILUWEIT[1,2], JEREMY BOUGOURE[1], PETER S. NICO[3], PETER K. WEBER[1], LYDIA ZEGLIN[2], DAVID D. MYROLD[2], MARKUS KLEBER[2]

[1]Lawrence Livermore National Laboratory, Physical and Life Sciences Directorate, Livermore, CA (*pettridge2@llnl.gov)
[2] Department of Crop and Soil Science, Soils Division, Oregon State University, Corvallis, OR
[3] Lawrence Berkeley National Laboratory, Earth Sciences Division, Berkeley, CA

Advancing understanding of soil organic-mineral interactions requires disentangling the complex interactions between soil mineral surfaces, decomposed organic compounds, and soil microbes in structurally intact soil. To avoid method-related artifacts that are associated with the common physical soil fractionation techniques, non-invasive high-resolution imaging techniques have been recently developed to simultaneously determine the molecular composition, source and fate of added OM, and location of OM within soil micro-aggregates. Simultaneous high-resolution chemical characterization and isotope tracing can be achieved by combining nano-scale imaging mass spectrometry (NanoSIMS) and spatially resolved spectroscopy (STXM/NEXAFS). These techniques allow precise, high-resolution, quantitative measurement of molecular and isotopic patterns in an undisturbed sample.

In a series of recent experiments, we combined these techniques to map organic carbon distribution, and image associations of organics with specific metal-oxide minerals in soil. In these experiments, we used ^{15}N- and ^{13}C-organic matter incubations and NanoSIMS imaging to track the fate of specific microbial and plant polymers. This has allowed us to measure preferential OM associations with Fe and Mn oxides and clay particles. Using synchrotron-based scanning transmission X-ray microscopy (STXM) analysis of the same microstructures, we can then measure the molecular class of these particles, for example, thin amine N coatings covering Fe (hydr)oxides, and microbial lipids coating montmorillonite particles.

These high-resolution imaging approaches are complementary to more traditional bulk analyses (^{14}C dating, NMR, density fractionation) and can yield mechanistic explanations for proceses which influence organic matter decomposition in soil.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Investigating controls on chemical weathering in the Cascade Mountains, Oregon

JULIE C. PETT-RIDGE[1*] WILL KRETT[1], NICK CURCIO[1], AND MARKUS KLEBER[1]

[1]Oregon State University Faculty of Soil Science, Corvallis OR, USA, julie.pett-ridge@oregonstate.edu

The steep volcanic terrain of the wet western side of the Cascade Range is likely to support relatively fast weathering rates. In this study we present data from a weathering study at H.J. Andrews Experimental Forest in the western Oregon Cascades. Our goal is to better understand controls on weathering processes, namely the controls on secondary mineral formation and on the magnitude of streamwater dissolved silica fluxes.

Controls on both temporal and spatial variability of streamwater silcia fluxes are investigated using 40+ year streamwater chemistry records from 7 small gauged watersheds within the site, and using synoptic sampling data from 40 locations across the site sampled in 1 day under baseflow conditions. Three sets of paired watersheds with contrasting land-use treatments (control, clear-cut, partial timber harvest, road building) but similar topography, aspect, bedrock and vegetation do not reveal significant land-use effects on streamwater silica fluxes. Over two orders of magnitude variation in instantaneous streamwater silica fluxes across the site is observed in the synoptic sampling. Stream temperature and landscape position correlate with silica flux, suggesting that deeper hydrologic flowpaths are the source of high silica fluxes.

10 soil pits were excavated, sampled, and characterized for physical and chemical properties including clay mineral XRD analyses and selective chemical dissolutions. Paired pits were sited to compare effects of slope aspect, bedrock type, and elevation. We found that higher elevation soils that experience more permanent winter snowpack contained smaller fractions of crystalline Fe-(hydr)oxides and larger fractions of organo-metal complexes relative to lower elavation soils. Among lower elevation soils, neither slope aspect (which corresponds to 30% difference in soil water flux), nor bedrock type (basalt versus andesitic breccia and tuff) varied consistently with soil properties. In this steep mountainous terrain (average slope 60-70%), geomorphic factors such as creep and treethrow appear to play a dominant role in controlling the degree of soil profile development.

Using this and previous data from the well-characterized H.J. Andrews study site, we evaluate weathering processes observed at both soil pit and small watershed scale in the larger context of controls on weathering. Specifically, we evaluate the role of climate variables (runoff, temperature, and snowpack persistence), topography, erosion rate, and hydrologic variables (soil water flux and distributions of fluid residence time) in controlling weathering fluxes as proposed in recent studies.