Examining Nanoscale Biogeochemical Controls on Metals, Radionuclides and Soil-Aqueous Particulate Organic Carbon using Conventional and Synchrotron-based Techniques

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Dominant controls on soil-sedimentary metal cycling often emerge through coupled physical, chemical, and biological processes, many of which remain enigmatic and transpire at nanometer scales. Accordingly, it is often critical to decipher such nanoscale processes in order to explain field-scale observations and improve process-based (e.g. reactive transport) models. Here, a synopsis of several studies is presented, where electrochemical, microfluidic and synchrotron-based tools are used to examine specific nano-cm scale biogeochemical-physical processes and their impact on the cycling of carbon and metals, including radium, mercury and methane. First, we illustrate how the combined use of scanning transmission X-ray microscopy (STXM) and ultra-high-resolution Fourier transform ion cyclotron resonance mass spectrometry (FTICR) provides unique and complimentary data for studying photochemical dissolution ("photodissolution") of particulate organic carbon (POC) within aqueous systems and exposed soils. Results and their implications are presented in context of how photochemical processes alter the reactivity of organic carbon toward reactivity with trace elements such as mercury. Second, we present results from bulk/x-ray microprobe (XAS, μXAS, μXRF) and electrochemical studies where biogeochemical processes controlling the fate of metals are examined within natural solids and artificial (microfluidic) pore networks; these studies illustrate how synchrotron-based techniques may be used to examine chemical/redox gradients spanning microns, and how this micro-scale heterogeneity influences the "bulk" behaviour of soil-sedimentary contaminants.