Electrical resistivity imaging of a deep coal mine discharge

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The biogeochemistry of iron cycling in acidic environments is quite complex where aerobic surface sediments and anaerobic subsurface sediments are often separated by only a steep redox gradient. The hydrodynamic conditions in these systems affect geochemical conditions that in turn affect microbial community structure. Hydrodynamic conditions can be observed directly at the surface, however, identification of e.g. areas of “fast” vs. “slow” flow are more difficult in the subsurface. To characterize flow paths and hyporheic exchange in the surface and shallow groundwater at an acid mine drainage (AMD) site, we used electrical resistivity imaging (ERI) at a stream emanating from a large abandoned deep coal mine in Cambria County, Pennsylvania. Because of the high conductivity (2,000 μS/cm) of the emergent AMD, we added clean fresh water (30 μS/cm) as a tracer to visualize the spatial and temporal distribution of the hyporheic exchange. Two-dimensional imaging of stream-groundwater exchange was collected from three locations in the study reach using three electrode transects across the stream. We were able to identify the location and spatial extent of a large artesian spring of AMD that contributed significant flow to the stream. Concurrent measurements of in-stream and in-well water chemistry were in good agreement with the inverted models of electrical resistivity. We believe this is the first report of a dilution tracer coupled with ERI for 2-D imaging of hyporheic extent in an acidic stream environment.

Uranium valence cycling with iron-rich phyllosilicates

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Iron-bearing phyllosilicate minerals are widely distributed in soils and sediments and often account for about half of the iron in soil. These minerals help establish the physical/hydrogeological conditions of subsurface redox transition zones because of their small size and limited hydraulic conductivity, and disproportionately buffer the redox conditions through the transition zone because they provide a large solid-phase reservoir of Fe(III)/Fe(II) (e.g., they are less susceptible to reductive dissolution as compared to oxides). We previously demonstrated that metal-reducing bacteria preferentially reduce soluble U(VI) over structural-Fe(III) in phyllosilicates; uraninite ($U^{IV}O_2(s)$) is rapidly reoxidized by phyllosilicate-Fe(III) (allowing U to serve as an electron shuttle); but at some thermodynamic endpoint, corresponding to an elevated concentration of structural Fe(II), phyllosilicate-Fe(III) can no longer oxidize uraninite. To better characterize this thermodynamic endpoint we conducted a series of abiotic experiments with synthetic uraninite and specimen phyllosilicate minerals, and with synthetic uraninite and clay-sized fractions from sediments collected from redox transition zones. We conducted these experiments using the unaltered clays (highest Fe(III) contents) and chemically-reduced clays (incremental increases in Fe(II) contents) to evaluate both kinetic and thermodynamic behaviour of their reactions with uraninite. Identical experiments were conducted where uraninite was replaced with non-sorbing, colorimetric redox indicators to quantify the reduction potential of the clays. Reaction products were characterized by U L_{III}-edge and Fe K-edge EXAFS spectroscopy and by TEM-electron energy loss spectroscopy.