# Integrated geophysical measurements for bioremediation monitoring: combing NMR, magnetic methods and SIP.

*University Led Research*

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Our research aims to develop borehole measurement techniques to monitor subsurface processes, such as changes in pore geometry and iron/sulfur geochemistry, associated with remediation of heavy metals and radionuclides. Previous work has begun to identify methods that are capable of surveying the subsurface environment. One such method, spectral induced polarization (SIP), has been used to monitor the progress of subsurface contaminant remediation; however, its interpretation is of limited value in isolation. In our research we aim to combine measurements from multiple geophysical methods, i.e. nuclear magnetic resonance (NMR), and magnetic susceptibility (MS), with SIP, to allow us to reduce or overcome the limitations associated with using one measurement alone. The integration of measurements from multiple geophysical methods, each sensitive to mineral form and/or mineral-fluid interfaces, will provide better constraints on subsurface biogeochemical processes and evolution of pore geometries and significantly improve our understanding of processes impacting contaminant remediation.

In the first year of the research project, NMR and MS borehole logging measurements were collected at the Rifle Integrated Field Research Challenge (IFRC) site. The Rifle IFRC site is located at a former uranium ore-processing facility in Rifle, Colorado. Although removed from the site by 1996, leachate from spent mill tailings has resulted in residual uranium contamination of both groundwater and sediments within the local aquifer. Since 2002, research at the site has primarily focused on quantifying uranium mobility associated with stimulated biogeochemical processes. Ongoing studies at the site include an acetate amendment strategy, in which stimulation of native microbial populations by introduction of a carbon source serves to alter local redox conditions and immobilization of uranium in insoluble forms. NMR and MS logging measurements were taken before, during, and after acetate amendment. Changes in these signals were expected to correlate with changes in redox conditions and iron speciation. Experimental data were collected from two wells upstream of the acetate amendment, used as controls, and from three downstream wells.

The MS measurements revealed vertically stratified magnetic mineralization, likely the result of a detrital magnetic fraction within the bulk alluvium. Data were highly replicable over the monitoring interval, with little to no change observed in the MS measurements, suggesting negligible production of magnetic phases (e.g. magnetite, pyrrhotite) as a result of sulfidogenesis. NMR measurements had high levels of noise contamination requiring significant signal processing, and ongoing analysis suggests that any changes due to stimulated microbial activity may be difficult to differentiate from simultaneous changes in water content.

In the second year of the project we will collect laboratory SIP, NMR, and MS measurements on columns packed with sediments from the Rifle IFRC site as the columns are amended with acetate; changes in the geochemistry and pore geometry inferred from these measurements will be verified by standard, independent laboratory measurements. We will integrate the field and laboratory results to develop a strategy for the interpretation of coupled SIP, NMR and MS measurements during biostimulation.