I. INTRODUCTION

To address the challenges associated with remediation of DOE contaminated sites, approaches are needed that can elucidate and predict reactions associated with coupled biological, geochemical, and hydrological processes over a variety of spatial scales and in heterogeneous environments. Our laboratory experimental work, which was conducted under controlled conditions, suggests that the geophysical methods have the potential to elucidate system transformations that often occur during remediation, such as the generation of gases and precipitates. In this new ERSP project, we will integrate hydrological, geochemical, and geophysical expertise and approaches to:

- Explore the potential of geophysical methods for detecting changes in physical, chemical, and biological properties at the field scale.
- Explore the joint use of reactive transport modeling and geophysical monitoring for improvements in both methods.

A brief review of our previously-conducted laboratory results are given in Section II. Section III describes the approach for our new project, which will have both laboratory and field-scale components. The field scale component will be conducted at the Rifle, CO site, which is described in Section IV.

II. PREVIOUS EXPERIMENTAL RESULTS

With EMSP support, we have recently investigated the utility of the following different geophysical techniques for detecting various system transformations at the column scale:

- Radar velocity measurements for measuring the evolution of gas during denitrification (Hubbard and Williams, 2004).
- Seismic measurements to detect onset of gas evolution during denitrification
- Salt Potential (SP) measurements for characterization of redox conditions. We have used SP methods to track the onset and location of microbial sulfate-reduction in saturated sediments at the laboratory scale during conditions of organic carbon amendment. The experimental results suggested the ability to measure the change in redox potential of sulfate-reduction during bioremediation (Williams et al., 2005).
- Geophysical monitoring of: parameters (such as gases, precipitates, and biofilms) within a heterogeneous environment. In this component, responses in saturated, porous media and test the models using the laboratory data.
- Stochastic framework that can be used with petrophysical models and measured data to enable a more quantitative interpretation of the geophysical model.
- In-situ measurements of: products (such as gases, precipitates, and biofilms) within a heterogeneous environment. In this component, responses in saturated, porous media and test the models using the laboratory data.

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Examples of a few of these results are briefly described below.

Monitoring Gas Evolution during Denitrification

Laboratory-scale biostimulation experiments were performed to assess the seismic and radar responses to gas generation using instrumented columns such as those shown in Figure 1. Using a three-phase mixing model (gas, water, solids) with radar velocity measurements, the volume of pore space filled with evolved N2 gas was estimated to be within 1% of that obtained using gravimetric measurements (Figure 2; Hubbard and Williams, 2004). Seismic methods indicated that the presence of gas in the pore space may have contributed to the signal (Figure 3; Williams et al., 2005).

Monitoring of Sulfide Production

Column scale studies (Figure 4) were performed to assess the influence of evolved aqueous sulfides as well as the development of petrophysical responses. After poisoning the system to undergo sulfate reduction, Desulfovibrio species were added to the middle of the column and the seismic and complex electrical responses were recorded. These studies showed how both seismic and complex electrical measurements could be used to detect sulfate reduction. The seismic method was found to be more sensitive than the electrical measurements (Williams et al., 2005; Ntarlagiannis et al., 2005).

REFERENCES

To address some of these questions, recent laboratory experiments have examined the change in the complex resistivity responses of a model phase (sulfide) by changing the reducing potential and sulfate-reduction. Figure 2 illustrates the change in the phase response of an initially oxidized, nitrate-reducing column moisture (0.6% water) following stimulation microbial alteration, both in-situ and sulfate-reducing strains isolated from the Rifle claysed fraction. In agreement with our 2004 field observations, the magnitude of the phase responses decreased following nitrate-reduction, most likely is the result of decreasing particle surface area following reordering of the clay particles (Figure 10). In contrast, exposure of the clays to H2S following sulfate-reduction led to blackening of the material (e.g. FeS) and an increase in the phase response (Figure 5). Such a result is in agreement with our 2005 field observations, where sulfate-reduction was found to be an important terminal electron accepting pathway. Ongoing work with native Rifle sediments is being performed to test similar hypotheses.

REFERENCES


