Environmental Management Science Program

Project ID Number 55300

3-D Spectral IP Imaging: Non-Invasive Characterization of Contaminant Plumes

F. Dale Morgan
Massachusetts Institute of Technology
Room E34-412
Cambridge, Massachusetts 02139
Phone: 617-253-7857
E-mail: morgan@erl.mit.edu

William Rodi
Massachusetts Institute of Technology
Room E34-458
Cambridge, MA 02139
Phone: 617-253-7855
E-mail: rodi@erl.mit.edu

David Lesmes
Boston College
Devlin Hall 320
140 Commonwealth Ave.
Chestnut Hill, MA 02167-3809
Phone: 617-552-0839
E-mail: lesmes@mail1.bc.edu

June 1, 1998

55300

3-D Spectral IP Imaging: Non-Invasive Characterization of Contaminant Plumes

F. Dale Morgan, Massachusetts Institute of Technology

William Rodi, Massachusetts Institute of Technology
David Lesmes, Boston College

Research Objective

The overall objective of this project is to develop the scientific basis for characterizing contaminant plumes in the earth's subsurface using field measurements of induced polarization (IP) effects. Three specific objectives towards this end are:

1. Understanding IP at the laboratory level through measurements of complex resistivity as a function of frequency in rock and soil samples with varying pore geometries, pore fluid conductivities and saturations, and contaminant chemistries and concentrations.
2. Developing effective data acquisition techniques for measuring the critical IP responses (time domain or frequency domain) in the field.
3. Developing modeling and inversion algorithms that permit the interpretation of field IP data in terms of subsurface geology and contaminant plume properties.

Research Progress and Implications

Laboratory Studies

Our laboratory experiments to date are described in Appendices A and B, which consist of two papers submitted to the annual SAGEEP conference (Frye et al., 1998; Sturrock et al., 1998). Our experiments involved measurements of complex resistivity vs. frequency on a suite of brine saturated sandstone samples. In one set of experiments, the fluid chemistry (pH, ionic strength, and cation type) was varied. In a second set of experiments, the microgeometry of the rock matrix was varied. The experiments showed that spectral IP responses are sensitive to subtle variations in both the solution chemistry and rock microgeometry. The results demonstrate that spectral IP responses have the potential of being sensitive indicators of in-situ chemistry and microgeometry, the latter of which may be related to the hydraulic properties.

Data Acquisition

We have been looking in some detail at the effects of electromagnetic coupling and how to practically deal with it. In this area, our results to date are summarized in Vandiver (1998).

Modeling and Inversion

Our progress in the development of modeling and inversion algorithms for IP is described in Appendix C, a paper submitted to the annual SAGEEP conference (Shi et al., 1998). We have developed algorithms for forward modeling and inversion of spectral IP data in 3-D media. The algorithms accommodate a general earth model with a complex electrical conductivity as a function of frequency and 3-D spatial position. Using regularization and optimization techniques, the inversion algorithm obtains a 3-D image of resistivity amplitude and phase for each frequency contained in the data set. We have begun testing our algorithms on synthetic data generated from a simple model of a contaminant plume. The complex resistivity parameters of the background medium and plume are based on the laboratory results described above.

Planned Activities

In addition to continuing studies in the above mentioned 3 areas, we will be conducting a detailed 2D IP survey at the Aberjona, Superfund Site in Woburn, MA.

Other Access To Information

Results of this research project were presented at The Symposium on the Application of Geophysics to Environmental and Engineering Problems, held March 1998 in Chicago and sponsored by the Environmental and Engineering Geophysical Society. The following three papers were presented and are published in the conference proceedings:

Frye, K.M., D.P. Lesmes, and F.D. Morgan, The influence of pore fluid chemistry on the induced polarization response of rocks and soils, SAGEEP Proceedings. pp. 771-781.

Shi, W., W.L. Rodi, and F.D. Morgan, 3-D induced polarization inversion using complex electrical resistivities, SAGEEP Proceedings. pp. 785-795.

Sturrock, J.T., D.P. Lesmes, and F.D. Morgan, The influence of micro-geometry on the hydraulic permeability and the induced polarization response of sandstones, SAGEEP Proceedings. pp. 859-869.

Vandiver, Amy, 1998, Analysis of the Effects of Inductive Coupling in Induced Polarization Surveys of Environmental Contaminants, MIT BS Thesis.