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Effects of Fluid Distribution on Measured Geophysical Properties for Partially Saturated, Shallow Subsurface Conditions

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FY2001 Annual Report for EMSP Project #70108

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Research Objective

Our goal is to improve geophysical imaging of the vadose zone. We will achieve this goal by providing new methods to improve interpretation of field data. The purpose of this EMSP project is to develop relationships between laboratory measured geophysical properties and porosity, saturation, and fluid distribution, for partially saturated soils. Algorithms for relationships between soil composition, saturation, and geophysical measurements will provide new methods to interpret geophysical field data collected in the vadose zone at sites such as Hanford, WA.

Research Progress and Implications

This report summarizes work after 20 months of a 3-year project. We modified a laboratory ultrasonics apparatus developed in a previous EMSP project (#55411) so that we can make velocity measurements for partially-saturated samples rather than fully-saturated or dry samples. Modifications included adding tensiometers and changing the fluid system so that pore fluid pressure can be controlled and capillary pressure can be determined. We made a series of measurements to determine properties of partially saturated Ottawa sand samples and are currently working on sand-clay samples. Future measurements will be made on a Hanford sample of sands from split-spoon cores from an uncontaminated site. Results from the measurements on Ottawa sand show that for pressure conditions equivalent to the top few meters of the subsurface, capillary forces can be of the same order as the externally applied stress. A fully drained sample showed velocities increasing over time due to chemical effects. Adhesion and capillarity at grain contacts affect wave amplitudes, velocities, and frequency content for the partially saturated case. We have used the LLNL x-ray facility and the DOE Advanced Photon Source (APS) at Argonne National Laboratory to perform x-ray computed tomography (XCT) imaging for several partially-saturated Ottawa sand and Lincoln sand samples. High resolution images from the APS allow us to image amount and distribution of fluids in homogeneous sand samples. We have analyzed previous measurements on dry sand-clay samples to understand how composition is related to measured velocities. We found that initially the compressional velocity increases with increasing clay content as clay cements the sand grains and initially fills pores, but then compressional velocity decreases when the sample behavior is controlled by a continuous clay matrix. Shear velocities decrease as a monotonic function of clay content due to the difference between the rigidity of quartz and the rigidity of clays. We are using rock physics methods to analyze the laboratory data and will develop algorithms relevant for interpreting field seismic data. Our results suggest that the planned approach for this research is appropriate, that microstructure is an important factor for measured geophysical properties, and that seismic field experiments should be designed to collect both compressional and shear wave velocity data and to collect wave amplitude as well as velocity information when possible. Results have been presented at several scientific meetings (including EMSP workshops) and in journal papers, as listed below.

Planned Activities

We plan to continue making laboratory measurements of compressional and shear velocities for partially saturated soils at low pressures, for the rest of this fiscal year. We will also continue to make XCT images of partially saturated samples during this fiscal year. In the third year, we will continue to use rock physics theories to interpret laboratory measurements to relate measured velocities to saturation and composition for soils. This work also will make use of results from a previous EMSP project (#55411) and other available geophysical data. We will focus on developing algorithms for relationships between composition, saturation, and geophysical measurements.

We are also networking with other current and former EMSP and EM project P.I.'s (e.g., C. Carrigan, LLNL; E. Majer and Jil Geller, LBL; D. Steeples, U. Kansas; R.J. Knight, Stanford/U. British Columbia; Mike Waddell, U. South Carolina) to plan possible future collaborations on field experiments to test the lab and theory results of this EMSP project, since this EMSP project is developing methods for improving interpretation of field seismic data used for subsurface imaging.

The lead P.I. also participated in the Non-invasive Characterization Work Group for the DOE Complex-Wide Vadose Zone Science and Technology Roadmap for Characterization, Modeling and Simulation of Subsurface Contaminant Fate and Transport.

Information Access

Copies of many of these documents may be viewed online or downloaded at the URL
http://www.llnl.gov/tid/lof/
by performing a search using the UCRL number of the document or the author name.

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