Project Title: Advanced High Resolution Seismic Imaging, Material Properties Estimation and Full Wavefield Inversion for the Shallow Subsurface :

Grant Number: DOE DE-FG07-97ER14827

Environmental Management Science Program (EMSP) project number: 73962

Publication Date: 14 June 2001

Lead Principal Investigator:

A. Levander
Center for Computational Geophysics
Rice University, Earth Science, MS-126
6100 Main Street
Houston, TX 77005
713-348-6064
alan@geophysics.rice.edu

Co-Investigator:

C.A. Zelt
Center for Computational Geophysics
Rice University, Earth Science, MS-126
6100 Main Street
Houston, TX 77005
713-348-4757
czelt@rice.edu

Co-Investigator:

W.W. Symes
Center for Computational Geophysics
Rice University, Computational and Applied Mathematics, MS-134
6100 Main Street
Houston, TX 77005
713-348-5997
symes@caam.rice.edu

Graduate Students: Diana Dana, Aron Azaria, Fuchun Gao, Peng Shen (all at Rice University)

RESEARCH OBJECTIVE: Develop and test advanced near vertical to wide-angle seismic methods for structural imaging and material properties estimation of the shallow subsurface for environmental characterization efforts.

RESEARCH PROGRESS AND IMPLICATIONS:

In July and August 2000, we conducted 3-D reflection, tomography, and downhole seismic studies at Operable Unit 2 (OU2) at Hill Air Force Base (HAFB) in Ogden, Utah. OU2 has been the subject of ongoing remediation efforts to remove dense nonaqueous phase liquids (DNAPLs) that contaminate a shallow (less than 20 m) aquifer. This study builds on initial results from our 2-D survey (Dana et al, 1999) that successfully demonstrated the capability of seismic techniques to image a buried paleochannel that acts as a contaminant trap for DNAPLs within the near surface area of the site (Dana, et al, 1999).

Background

OU2 is one of nine designated superfund sites on HAFB. It is located on the eastern edge of HAFB (Figure 1). The site is on the eastern edge of a mesa overlooking the Weber Valley, a rural agricultural area. The near surface environment consists mostly of Quaternary sands, gravels, and silts over a thick (up to 60 meters) clay layer into which the base of the channel is cut. The clay layer acts as a barrier for the downward migration of contaminants (DNAPLs) into the local groundwater system. The DNAPL have collected in the base of a paleochannel that runs north to south through OU2. Monitoring well data was used initially by the ongoing remediation program to locate the channel. Although over 200 monitoring wells have been drilled, knowledge of the subsurface environment is still not adequate to efficiently remove the DNAPL. Our 2-D pilot study (Dana et al, 1999) demonstrated the viability of seismic methods to image the near subsurface geologic environment (upper 20 m) of OU2, providing contiguous coverage of the near surface and "connecting the dots" of well information (Figure 2).

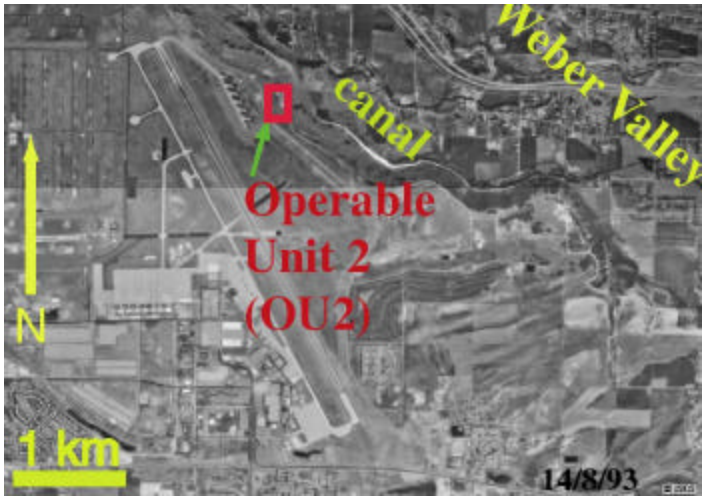


Figure 1 – Aerial photo of Hill Air Force base with Operable Unit 2 (OU2) indicated (adapted from USGS).

Methods

Using data from the 2-D study, the 3-D study was designed to image the paleochannel along its strike, maximizing the obtained image in a cost-effective manner (Figure 3). The four-week experiment included 3-D seismic reflection, 3-D tomography, six check shot surveys in 15m boreholes for velocity estimation, and two vertical seismic profiles. A 223-caliber rifle was used as the seismic source in all experiments, producing frequencies from 40 Hz to greater than 300 Hz. Approximately 6000 shot records were taken in the various experiments; the experiment at times generated nine Gbytes of data per day.

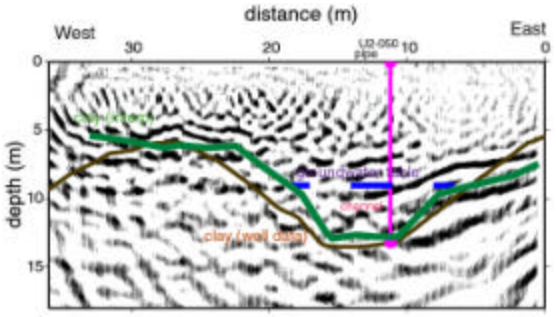
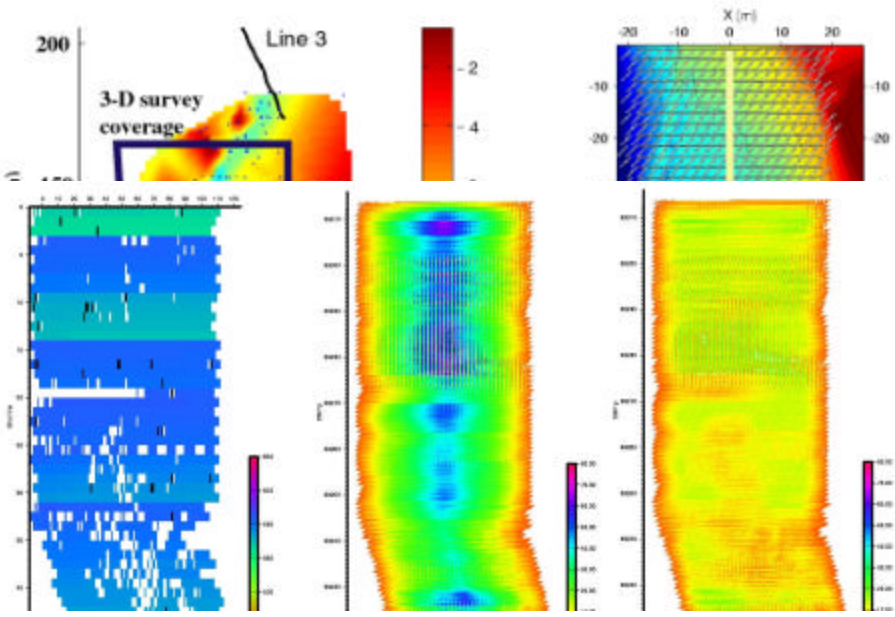


Figure 2 - Prestack depth mig
the profile of the channel. Tl
location is shown with logge
monitoring wells. See Figure



The 3-D reflection and tomography experiments both occupied an area of 95m by 36m, covering the paleochannel from north to

south with the inline direction profiling the channel. The experiment utilized over 600 RefTek Texan instruments, a non-cabled single channel recording system. For the reflection experiment, the instruments were deployed in swaths of six receiver lines 2.1m apart, with geophone intervals in the inline direction of 0.35m. The shot pattern was a rotated brick pattern with 0.35m shot intervals in the inline and cross line directions, producing a nominal 52-fold survey. Forty-four shot lines were completed (Figure 4). A Geometrics 60-channel recording system was placed along the center of the channel to collect data for comparative analysis. The tomography experiment covered the survey area using all of the Texan units spread over the entire 45 line receiver grid. A 2.8 m geophone interval for the inline direction employed 13 or 14 receivers for each line, maintaining the 2.1m cross line spacing from the reflection experiment. Shots were made at each of the geophones, providing a source-receiver offset of 0.3 to 102 m. Three-component downhole geophones were used to conduct check shot surveys of six wells to collect velocity data for the site, and with the Geometrics system, also used to conduct a VSP between two of the wells.

Data quality appears to be excellent, despite a high level of cultural noise from remediation equipment (60-120 Hz harmonics) and from jets. The shot gathers show strong reflections with conflicting dips, characteristic of steeply dipping features. The tomography data shows refracted arrival times, which will be used in a tomographic inversion to describe the seismic velocities of the near surface (Figure 5).

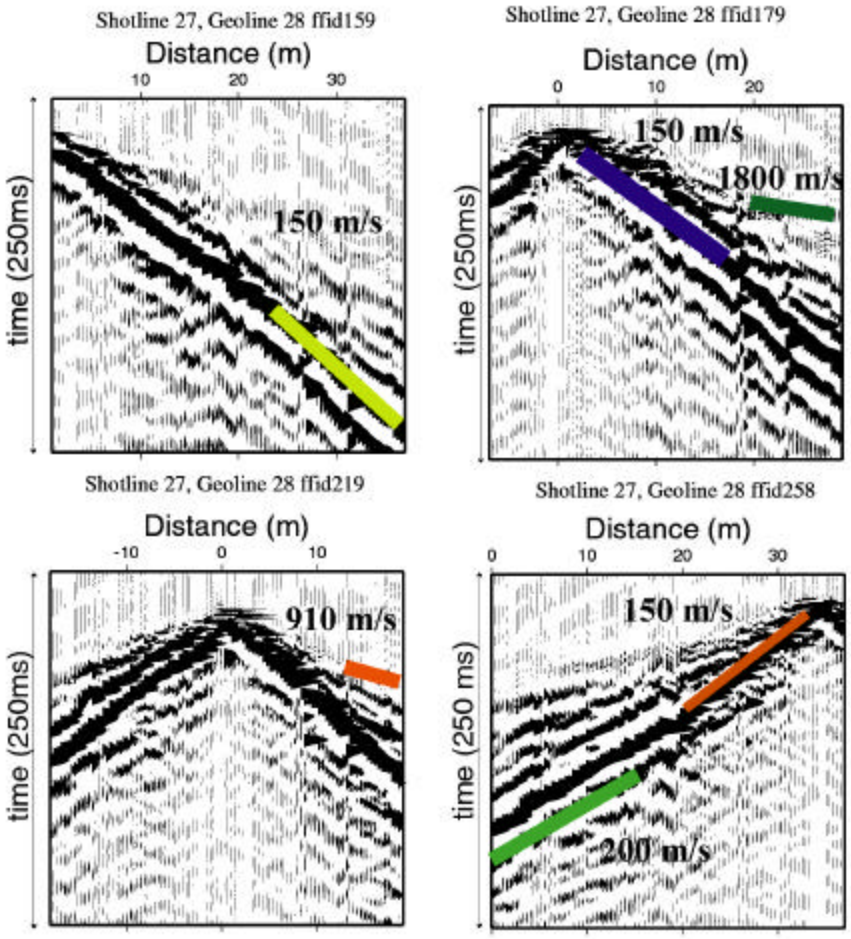
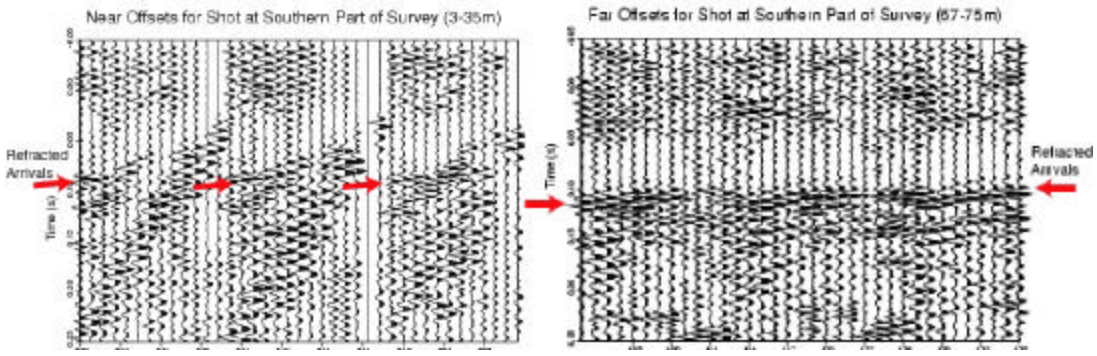


Figure 5 – Shot gathers from the reflection survey (above). Velocities of various direct arrivals, refractions and reflections are indicated. Near offset (3-35 m) and far offset (67-75 m) traces for a single shot from the tomography experiment with refracted arrivals are shown below.



Results

Geometry has been assigned and data processing and analysis of the reflection data are ongoing. RMS velocities measured by the check shot surveys agree with results from the 2-D survey. 3-D Kirchhoff depth migration, inversion and migration velocity tools are being developed for use on the data set. Arrival times of the refracted waves from the tomography data are being picked for use in a tomographic inversion to describe the seismic velocities of the near surface. The tomographic approach employs regularization to smooth the model perturbations with respect to a reference model. The background model incorporates a priori observations (monitoring well information) that constrain the possible solutions as well as provide quality control on the final velocity model. A well resolved velocity model should illustrate the presence of a channel feature over the target area. Results from the tomography data, VSP and check shot data, coupled with those from 3-D processing and analysis of the reflection data set should provide an adequate picture of the paleochannel to support remediation activities.

References

Dana, D., Zelt, C., Levander, A., 1999, "High-resolution seismic survey over a near-surface contamination site" in Society of Exploration Geophysicists International Exposition and Sixty-Ninth Annual Meeting, Expanded Abstracts, pg. 579-581.

INTERA, Inc., November 1997, AATDF Surfactant/Foam Process for Aquifer Remediation, prepared for the Advanced Applied Technology Demonstration Facility.

Acknowledgements

We would like to thank Jon Ginn (HAFB), Duke Engineering, and the PASSCAL Program of IRIS for providing instrumentation. We would also like to thank Dan Wisecup for providing technical support for our survey design and the international volunteers who participated in the field experiment. The PASSCAL Program of IRIS and the University of Texas at El Paso provided invaluable field and instrumentation support. This experiment and data analysis is funded by a grant from the U.S. Department of Energy (DE-F607-97ER14827).

PLANNED ACTIVITIES:

Over the next year we plan to complete our analysis of the 3-D reflection and tomography data, as well as the VSP and check shot data, and this should provide an adequate picture of the paleochannel in three dimensions to support remediation activities.

INFORMATION ACCESS:

http://terra.rice.edu/department/ccg/high-res/

CCG members homepages:

http://terra.rice.edu/department/people.html
http://www.caam.rice.edu/caam/caam-directory.html