5.4 THREE-DIMENSIONAL THREE-COMPONENT SEISMIC IMAGING FOR SITE CHARACTERIZATION

TECHNOLOGY NEED

This technology addresses the overall need to expedite site characterization with nonintrusive methods and is applicable to the Plumes and Landfill Focus Areas as well as the Innovative and Crosscutting Programs. Typical applications are characterizing the hydrogeologic framework (e.g., bedrock channels, clay layers, faults, fractures, and porosity) that controls contaminant transport and fate, identifying soil or waste heterogeneity and integrity, and defining and delineating trench and pit boundaries.

The Technology Need Assessment report details site-specific needs throughout the DOE complex. The U.S. Department of Defense (DoD), the Environmental Protection Agency (EPA), and other government entities also require the best available technologies to conduct characterizations that can supply data for input into Records of Decision.

TECHNOLOGY DESCRIPTION

Higher resolution and additional information about the subsurface is possible with combined one-component (1C) compression-wave and two-component (2C) shear-wave data (i.e., three-component [3C] data), as compared to only a single component of data. Because the shear-wave velocity of most subsurface materials is less than the compression-wave velocity and because the dominant recovered frequencies are similar for both wave types in many areas, shear-waves are able to map much thinner features. In addition, 3C data allows determination of anisotropy. Anisotropy, which is defined as variations of a physical property depending on the direction in which it is measured, suggests that features resulting from forces other than regional geologic structure (i.e., faults and fractures) may be present in a volume. These features may include preferred grain orientation, periodic layering, and depositional or erosional lineation, and may be correlatable to preferential contaminant transport pathways.

Surveys with three-dimensional (3D) seismic methods allow investigation of a volume when surface access may be restricted because of high contamination levels. With the 3D/3C seismic method, data acquired along separate source and receiver lines outside a restricted volume provide information that can be interpreted for zones within the restricted volume. 3D seismic data can be processed so that selected profiles within a volume may be viewed from any angle and specific time or depth horizons may also be displayed and interpreted.

Given restricted entry into contaminated areas and the high cost of well completion, 3D/3C seismic technology can be a valuable means of nonintrusively characterizing hydrogeologic framework and siting monitoring wells. Other applications include determining soil or waste heterogeneity and integrity, and defining and delineating trench and pit boundaries. A full-scale demonstration will enable the 3D/3C seismic technology to be developed to a point where it can be transferred to private industry and applied at numerous suitable sites.

Benefits

The 3D/3C technology has three primary benefits over the baseline 2D/1C and 3D/1C technology: (1) improved characterization, (2) reduced health and environmental risks, and (3) reduced costs. A 3D/3C seismic survey will allow a uniform 3D investigation of an area, thus minimizing the possibility that the area will need to be resurveyed because of less-than-optimum placement of 2D survey profiles. This technology minimizes the number of times an area must be accessed for surveying and maximizes the amount of information possible.

Collaboration/Technology Transfer

The joint participants in this task, representing DOE, the private sector, academia, and another government agency, have collaborated on the common goal to develop feasible near-surface 3D/3C seismic technology. Emphasis has been placed on providing technology to the private sector that is suitable for near-term application to specific DOE EM programs. Bay Geophysical Associates, Inc., the private sector joint participant, has gained sufficient knowledge from this project to become a leader in the commercialization of the technology. The final report represents accomplished work and will be a vehicle for the transfer of this technology.

Accomplishments

- Acquired baseline surface and borehole data in FY94 at Savannah River Site (SRS)
- Completed surface 2D/1C and surface-to-hole analyses. Published report in FY95
- Developed 3D/3C seismic processing software and conducted data analyses in FY95/96
- Published 3D/3C Seismic Technology Baseline Report in FY96

Figure 5.4-1 presents a graphical representation of reflection midpoints and the subsequent subsurface coverage of the 3D/3C method. Seismic energy was generated at 13 source points along Line A and received by 24 geophones along Line C. In an area of relatively flat dip (as at SRS), the midpoint between the source and receiver is taken as the subsurface reflection point. Reflection midpoints for geophone numbers 1 and 24 and sources 1 through 13 are highlighted. The shaded area in Figure 5.4-1 represents the total subsurface coverage of all 13 sources and 24 geophones. A section line comprising any combination of sources and receivers can be displayed and interpreted. Thus, 3D seismic surveys allow investigation of an area when access may be restricted. For example, portions of the shaded subsurface coverage area may have restricted access because of high contamination levels, but 3D seismic data can still be acquired for interpretation from within that restricted area.

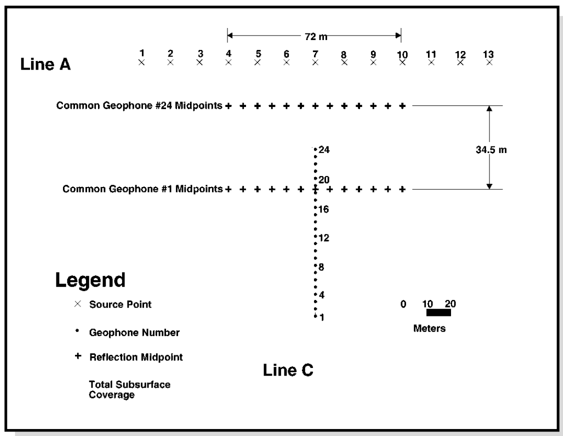

Figure 5.4-1 Three-dimensional reflection seismic coverage (shaded area). Reflection midpoints are highlighted for geophone numbers 1 and 24, sources 1 through 13.

Compressional-wave (P-wave) and shear-wave seismic time sections for common geophone midpoints 4 through 15 were converted to depth by applying velocities and static corrections, and the predominant reflectors were digitized. Figure 5.4-2 presents a 3D representation of the P-wave reflectors. Geologic horizons corresponding to a calcareous sandstone layer, the Green Clay, and the Ellenton Clay were interpreted using synthetic seismograms and depths from drilling logs for surrounding boreholes. Each one of these geologic horizons acts as an aquiclude in the survey area. Note that the upper two reflectors are absent in relatively large areas, while the lower reflection is also absent in one localized area. The interpreted topography and the presence or absence of geologic horizons indicate possible pathways for contaminants. For example, a contaminant above the calcareous sandstone layer could conceivably migrate down through the Green Clay and the Ellenton Clay aquicludes into the underlying aquifer.

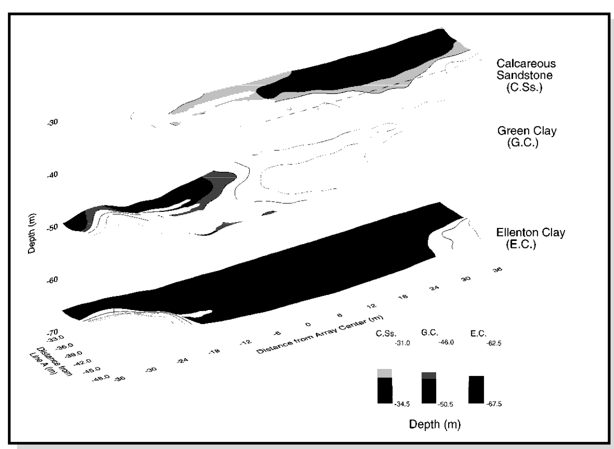

Figure 5.4-2 P-wave seismic reflectors for a portion of a shaded subsurface coverage area shown in Figure 5.4-1. Note varied topography and presence or absence of interpreted geologic horizons.

TTP Information

3D/3C Seismic Imaging for Site Characterization technology development activities are funded under the following Technical Task Plan (TTP):

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Contacts

James C. Hasbrouck
Principal Investigator
Rust Geotech
P.O. Box 14000
Grand Junction, CO 81502
(970) 248-6714

Dennis Olona
U.S. Department of Energy
Albuquerque Operations Office
P.O. Box 5400
Albuquerque, NM 87185-5400
(505) 845-4296

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