Environmental Field Geophysics

Crosswell Seismic Imaging

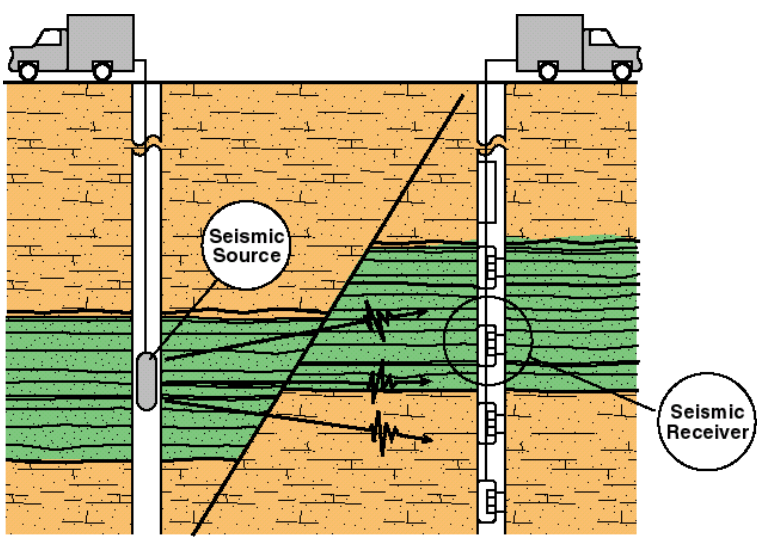
Need

Characterization of waste sites and monitoring of remediation processes are difficult to achieve noninvasively. Seismic crosswell imaging can provide valuable geophysical information about the subsurface with relatively little intrusion into the site, especially if preexisting boreholes are present. Crosswell images can be used to determine the seismic velocity structure of the site (characterization), and changes in the image over time, as determined by multiple surveys, can be effectively used for monitoring processes such as air sparging. Because changes in soil saturation are reflected in changes in seismic velocity, crosswell imaging is an effective tool for monitoring of some waste remediation processes.

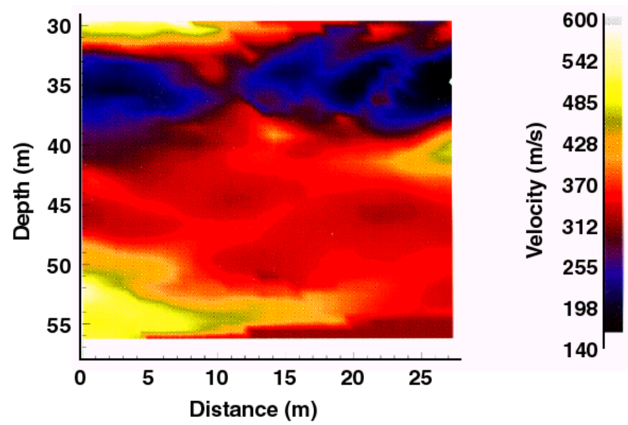
Description

Crosswell seismic imaging provides an estimate of the seismic velocities in the two-dimensional plane between two boreholes. Given suitable hole locations and a sufficiently energetic seismic source, this technique can yield an accurate picture of the subsurface in terms of seismic wavespeed. While a single survey is of use in site characterization, repeated surveys over time can provide useful monitoring information for site remediation.

The success of a crosswell survey depends on the strength, wavetype, and frequency range of the downhole seismic source, the characteristics of the seismic receiver, the distance between the two boreholes, and the geological characteristics of the site. While the concept of crosswell seismic surveys is not a new one, only select organizations have significant experience in conducting crosswell surveys and acquiring useful seismic data. Sandia National Laboratories has collected crosswell data at a number of locations, including DOE's Savannah River and Hanford sites, and has used and compared a variety of seismic sources for environmental applications (see Elbring, 1995). A variety of downhole sources have been developed. Some provide primarily P-wave energy (e.g., Bolt airgun),



Schematic of a crosswell seismic imaging experiment while others more efficiently generate S waves (e.g. Sandia magnetostrictive source and hydraulic source). For environmental applications, it is important to have a healthy high-frequency (several hundred Hz) output from the source in order to achieve reasonable resolution. In this area, shear wave sources have an advantage due to the higher achievable resolution obtainable due to slower S-wave velocities in soils. Sandia's magnetostrictive borehole source can, for example, produce useable shear-wave energy up to 2000 Hz; good signal-to-noise has been demonstrated for this source in boreholes more than 200 feet apart (Cutler et al, 1997).



Example of seismic shear velocity variation from a crosswell experiment at the Savannah River Site, South Carolina

There are a variety of downhole receivers available for crosswell surveys; the most important factors are the available borehole size and the frequency characteristics. A survey is run by positioning the source in one borehole and recording at a suite of depths in the other borehole. The source is moved to another depth in the hole and the process repeated until there are a full set of source-receiver combinations sampled. The data are typically inverted for velocity using a back-projection tomography scheme; intermediate data processing steps are required, particularly for swept-frequency sources, which, like surface vibrators, require cross-correlation to recover the proper waveform.

Sandia has performed crosswell surveys and imaged the resulting data at a number of locations, including Savannah River, the Weeks Island, LA site of the Strategic Petroleum Reserve, the Hanford site, and the M-site experimental facility near Rifle, CO. These field tests have provided significant practical experience in acquiring crosswell data and imaging for environmental applications.

References

Cutler, R. P., G. Sleefe, and R. Keefe., Developent of a Magnetostrictive Borehole Seismic Source, SAND97-944, Sandia National Laboratories, Albuquerque, NM, 87185, 1997.

Elbring, G. J., Crosshole Shear-Wave Seismic Monitoring of an In Situ Air Stripping Waste Remediation Process, SAND91-2742, Sandia National Laboratories, Albuquerque, NM 87185, 1992.

Elbring, G. J., Comparison of Lower-Frequency (< 1000 Hz) Downhole Seismic Sources for Use at Environmental Sites, Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems, SAGEEP '95, Environmental and Engineering Geophysical Society, 591 - 599, 1995.

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