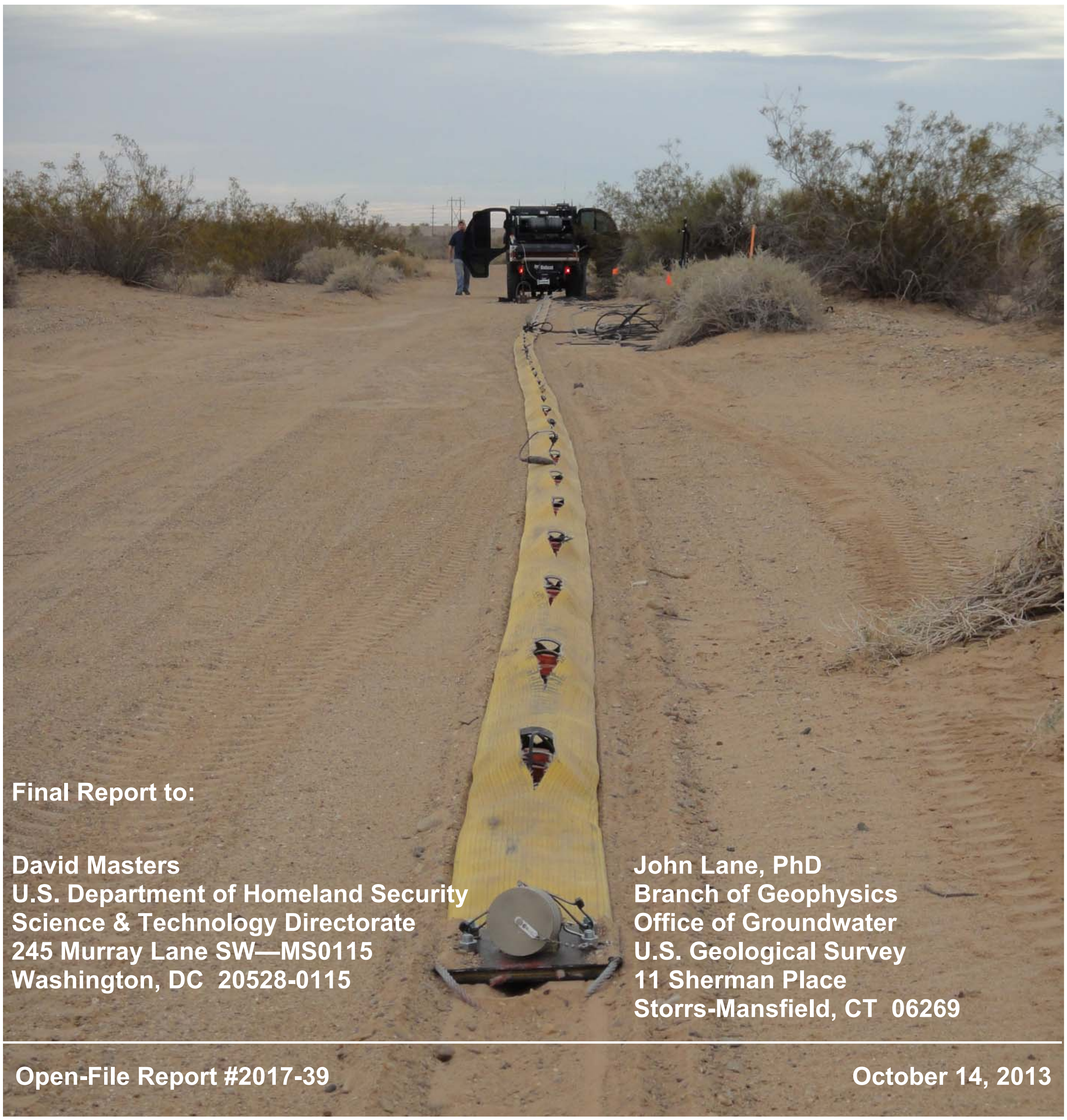
Final Report: Seismic Analysis at Strategic Border Sites Trip 1: DTRA-SL2(C)

Richard D. Miller, J. Tyler Schwenk, Julian Ivanov, Shelby L. Peterie,
Brett E. Judy, J. Jordan Nolan, Brett Wedel,
Ryan Nelson, Brett Bennett, and Joe Anderson

Kansas Geological Survey
1930 Constant Avenue
Lawrence, KS 66047



Final Report to:

David Masters
U.S. Department of Homeland Security
Science & Technology Directorate
245 Murray Lane SW—MS0115
Washington, DC 20528-0115

John Lane, PhD
Branch of Geophysics
Office of Groundwater
U.S. Geological Survey
11 Sherman Place
Storrs-Mansfield, CT 06269

Open-File Report #2017-39

October 14, 2013

 This study was conducted in complete compliance with ASTM Guide D7128-05. All data, interpretations, and opinions expressed or implied in this report and associated study are reasonably accurate and in accordance with generally accepted scientific standards.

Final Report: Seismic Analysis at Strategic Border Sites
Trip 1: DTRA-SL2(C)

Summary

The Kansas Geological Survey acquired 14 lines of active seismic data at 12 sites during two trips to the US-Mexico border. Data were processed using multi-channel analysis of surface waves (MASW), refraction tomography, and surface wave inversion to obtain 2-D profiles of shear-wave velocity (Vs), compressional-wave velocity (Vp), and seismic quality factor (Qs and Qp) for the near surface. This report contains final processing and results for the DTRA-SL2(C) site.

Data Acquisition

One line of seismic data (~275 m) was acquired on February 25, 2012, at DTRA-SL2(C) coincident with the USGS ERT profile (Figure 1). The system of sources and receivers, collectively, is the Active Seismic Imaging (ASI) system developed by and fabricated at the Kansas Geological Survey (Figure 2). Seismic sources were an accelerated weight drop for surface wave and long-offset compressional energy, sledge hammer and steel plate for near-offset compressional-wave energy, and sledge hammer and shear block for shear-wave energy. Seismic receivers were located in a towed 48-channel 3-component (3-C) land streamer with 48 stations separated by 1.2 m. Receivers were single 4.5 Hz and two 14 Hz horizontal (SV orientation) geophones (Figure 3). Seismographs were a Geometrics Geode distributed system. The survey was fixed spread with variable 0-57.3 m source offset (Figure 4) to obtain sufficient seismic sampling within the depth of interest. Individual receiver spreads overlapped by half of a spread.

Downhole data were acquired on August 15, 2013, with a 3-C downhole Geostuff geophone (Figure 5). The shallowest receiver station was located at a depth of 1.5 m, and receiver station spacing was 0.75 m (Figure 6). A repeatable shear and compressional 9 kg hammer source, developed and fabricated at the Kansas Geological Survey, was located at 3 m from the borehole (Figure 7). A 2.7 kg sledge hammer and steel plate were located at 22.9 m from the borehole.

For both the surface and downhole seismic surveys, multiple shots were acquired and recorded separately for each unique shot/receiver configuration and stacked during processing to minimize ambient noise (Figure 8) and increase the signal-to-noise ratio.

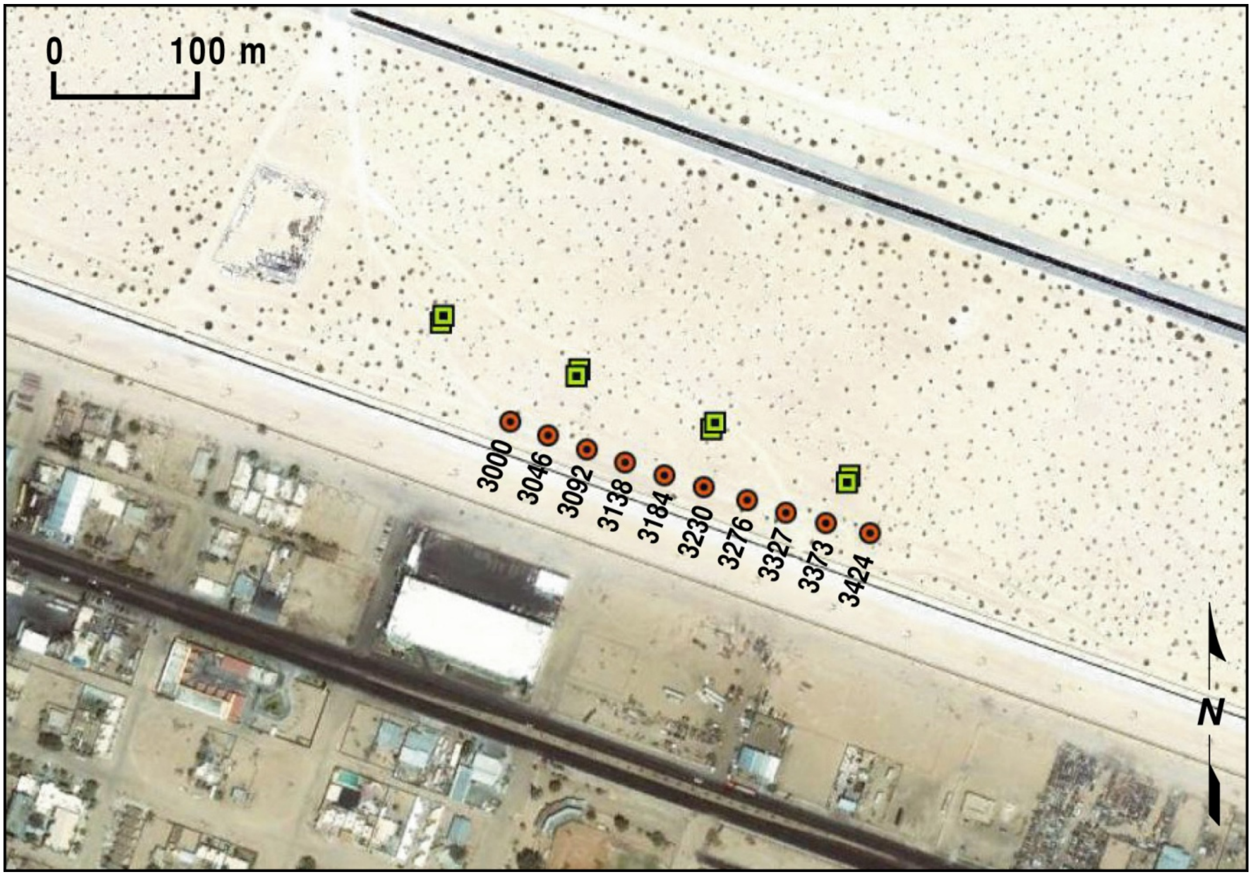


Figure 1: Aerial photo of DTRA-SL2(C) and the location of the active seismic line.

Figure 2: Sledge hammer and shear block source next to the ASI and detached 144-channel 3-C land streamer.

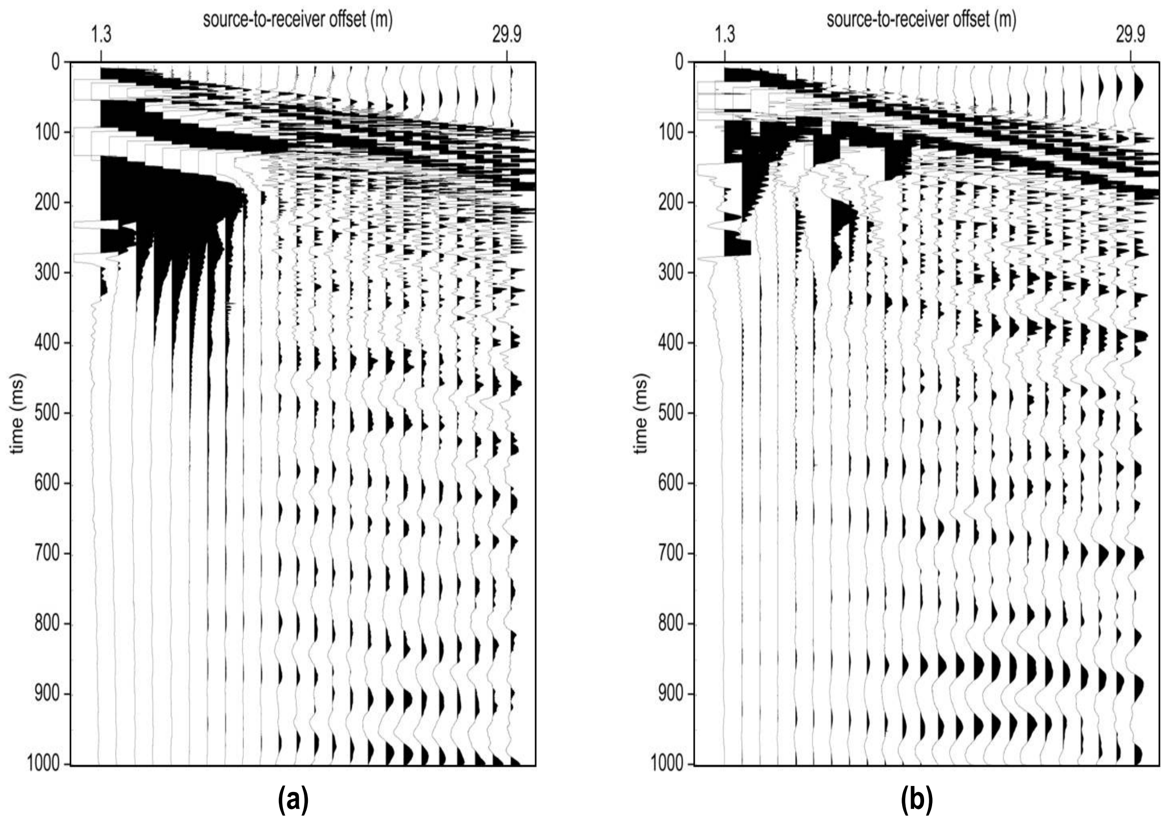


Figure 3: Representative off-end shot gathers at DTRA-SL2(C). (*a*) Sledge hammer and shear block source recorded with shear 14 Hz geophones, SV orientation. (*b*) Hammer on a steel plate source recorded with vertical 4.5 Hz geophones.

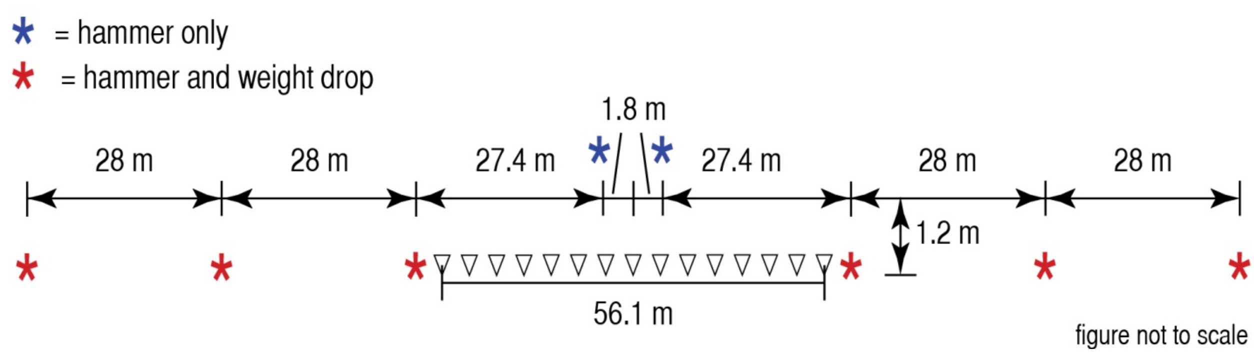


Figure 4: Diagram indicating all shot point locations relative to a single receiver spread.

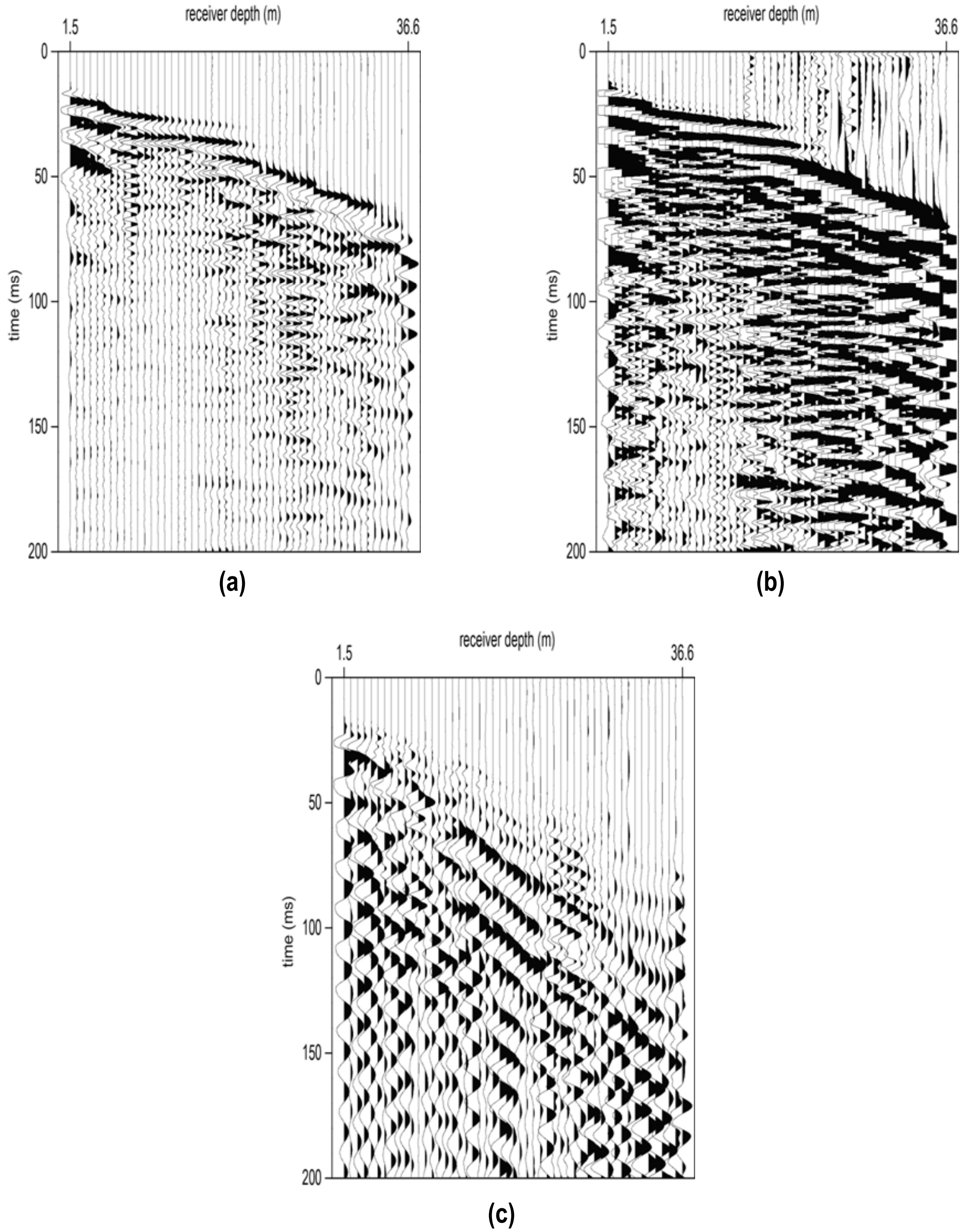


Figure 5: Representative downhole (*a*) vertical, (*b*) processed vertical, and (*c*) shear records at DTRA-SL2(C).

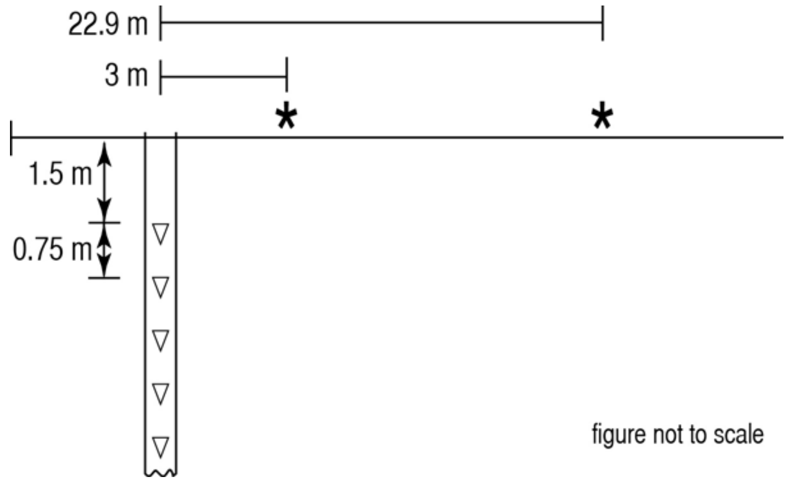


Figure 6: Downhole seismic field layout.

Figure 7: Downhole seismic acquisition utilized at DTRA-SL2(C).

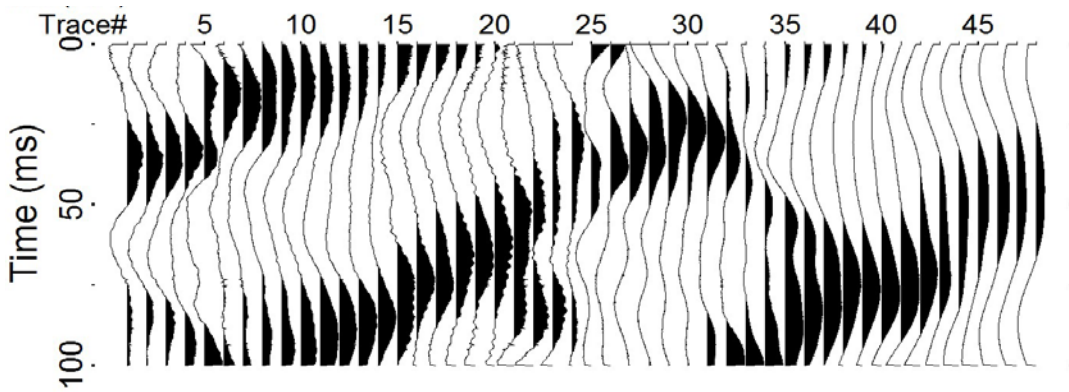


Figure 8: Representative ambient noise recorded at DTRA-SL2(C). Traces 1-24 represent the 14 Hz shear geophones and traces 25-48 represent the 4.5 Hz vertical geophones.

Data Processing

Multichannel-analysis of surface waves (MASW) was used to analyze dispersive Rayleigh-wave energy and estimate shear-wave velocity (Vs). Fundamental-mode energy was interpreted and inverted using a weighted, damped least-squares approach (Xia et al., 1999), resulting in a 2-D Vs profile. Refraction tomography with 1.2 x 1.2 m cell size was used to estimate Vs and P-wave velocity (Vp). Joint-analysis of refractions and surface waves (JARS, Ivanov et al., 2010) was used to constrain the non-uniqueness inherently involved in refraction inversion, resulting in physically realistic 2-D Vs and Vp profiles. Shear- and compressional-wave seismic quality factors (Qs and Qp, respectively) were obtained using a surface wave inversion technique (Xia et al., 2010). Average and interval Vp and Vs were calculated using the arrival time of the direct P-wave and S-wave, respectively, and pathlength from the seismic source to each receiver depth. Shear wave records were numerically rotated to orient the recorded shear traces in the vertical (SV) and horizontal (SH) polarization directions (Di Siena et al., 1984). The direct P-wave and S-wave were isolated on vertical and shear records, respectively, and the spectral ratio method was used to estimate Qp and Qs for each lithology identified in drilling notes (Tonn, 1991; Hasse and Stewart, 2004). The velocity and quality values calculated from downhole data were used to constrain inversion and improve accuracy of the results obtained using surface seismic methods.

Final Results

MASW

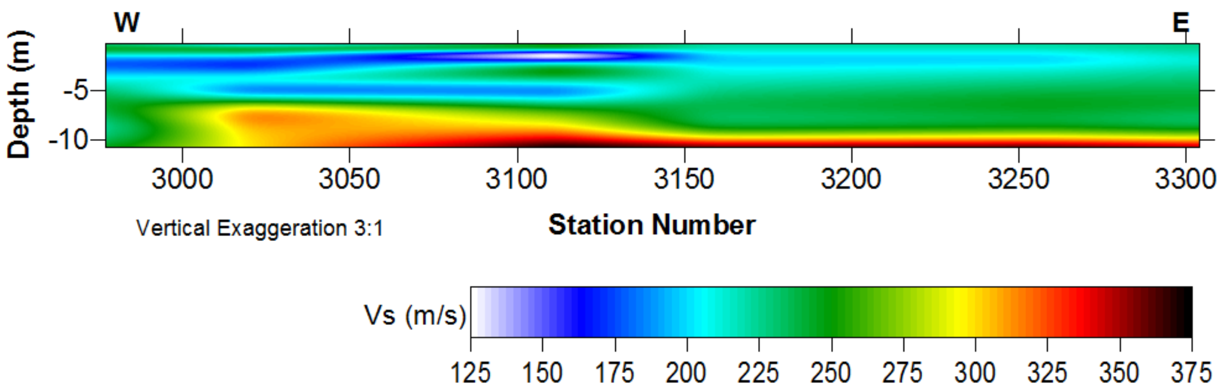


Figure 9: MASW Vs profile at DTRA-SL2(C).

Downhole Vs

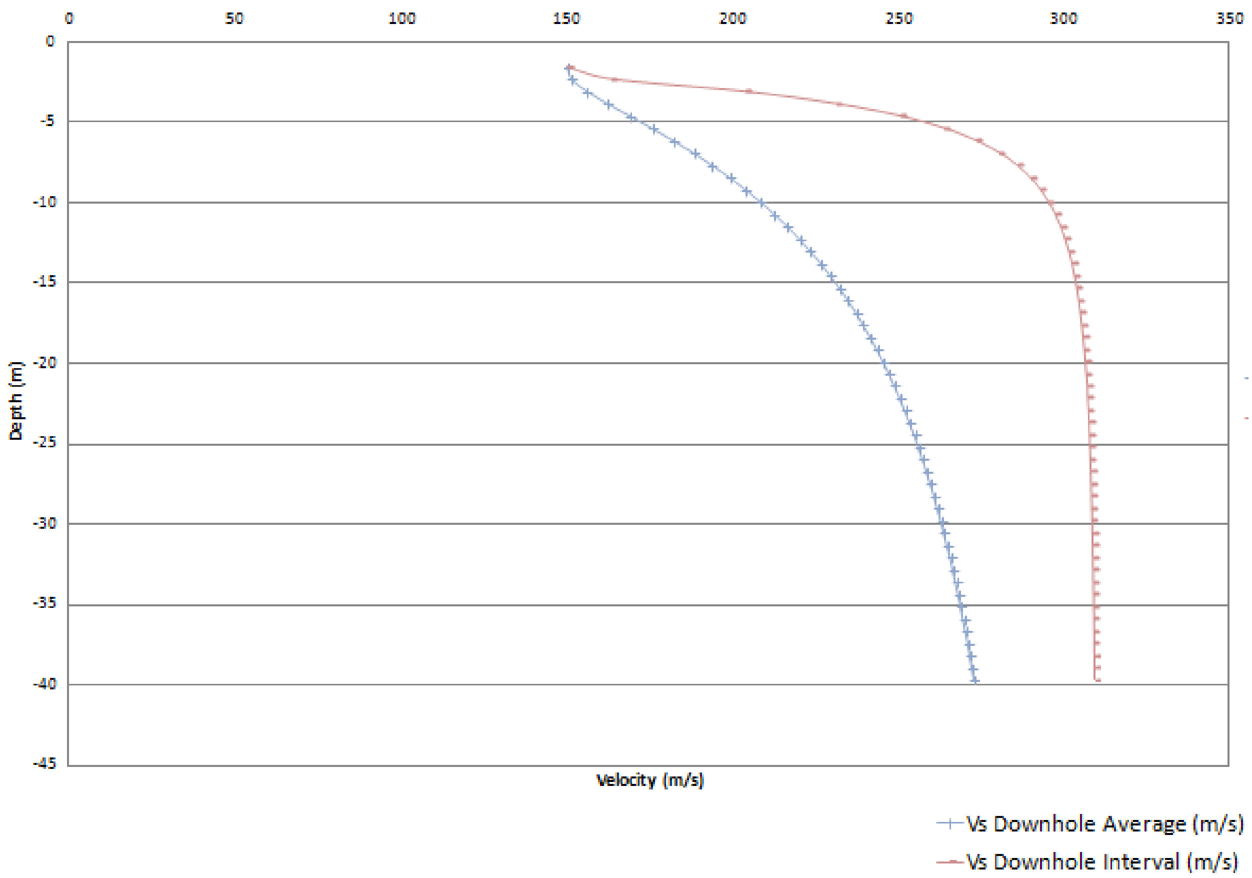


Figure 10: Downhole Vs profile at DTRA-SL2(C).

Downhole Vp

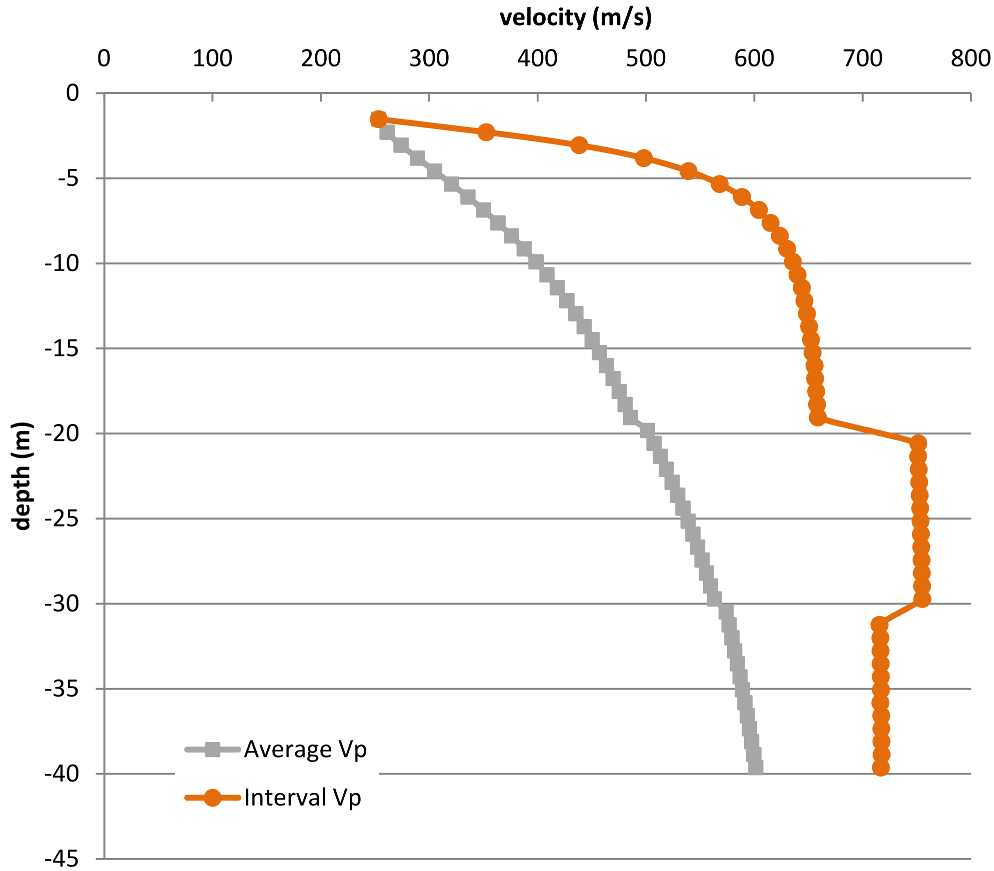


Figure 11: Downhole Vp profile at DTRA-SL2(C).

Vs Tomography

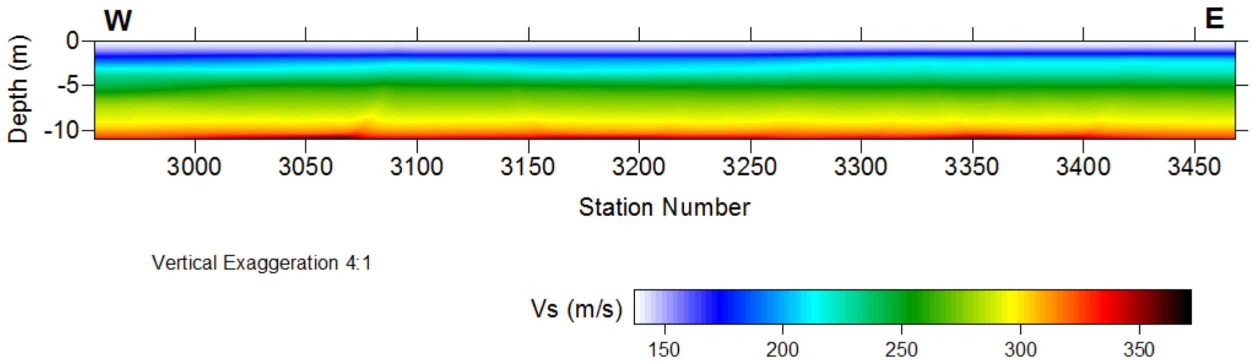


Figure 12: Vs tomography profile at DTRA-SL2(C).

Vp Tomography

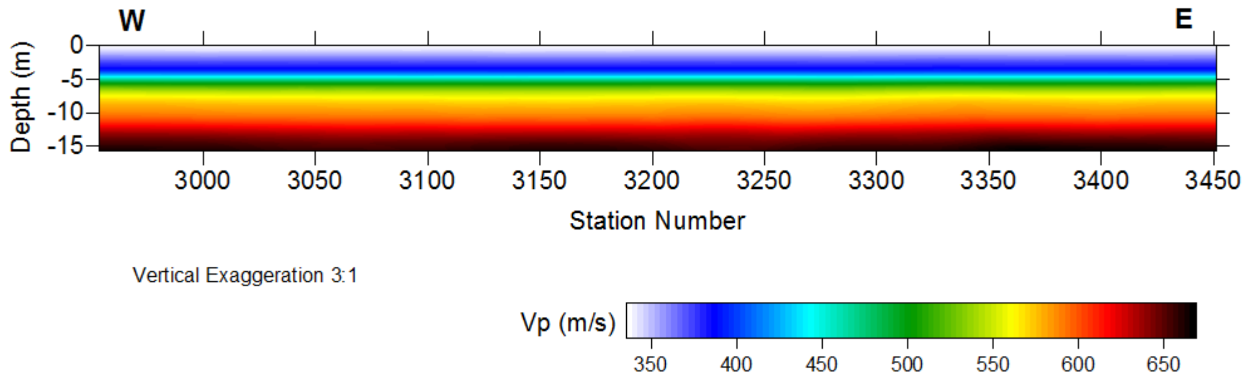


Figure 13: Vp tomography profile at DTRA-SL2(C).

Downhole Qs

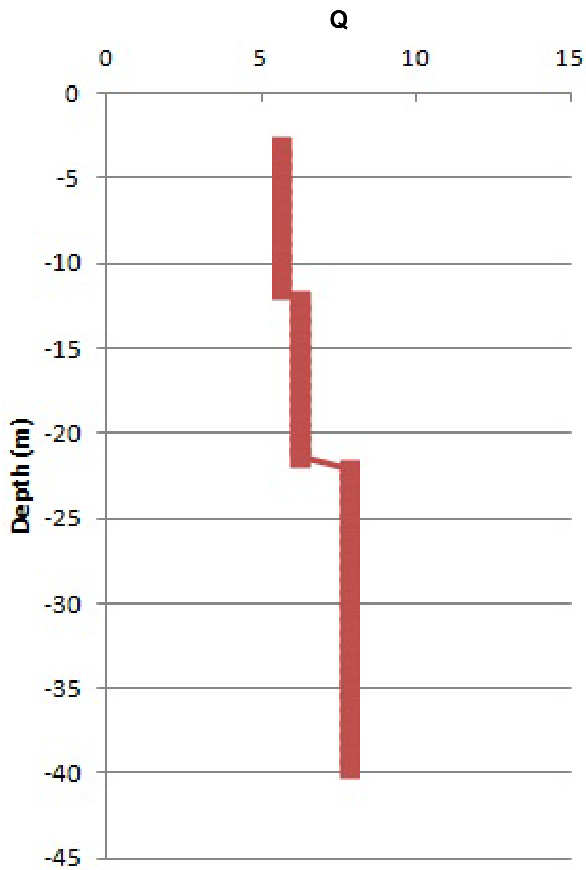


Figure 14: Downhole Qs profile at DTRA-SL2(C).

Downhole Qp

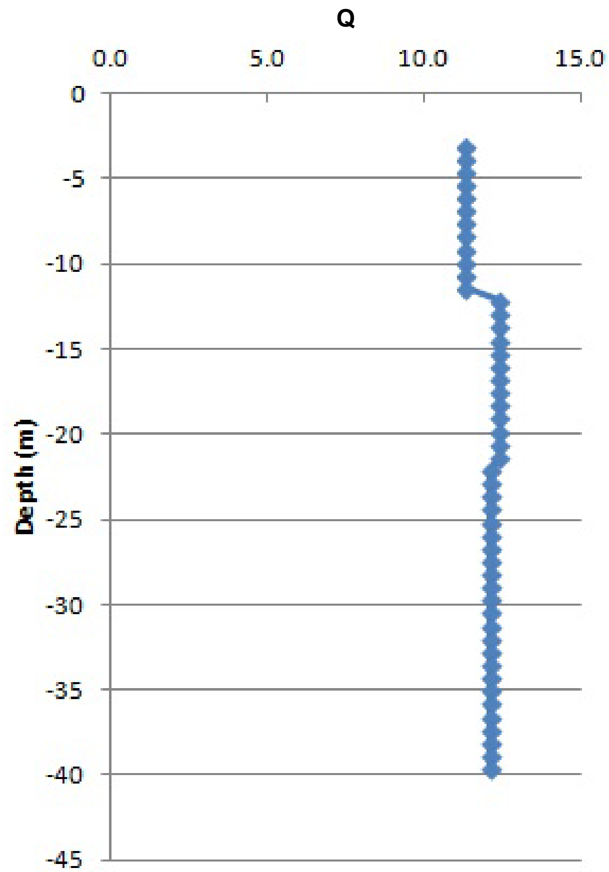


Figure 15: Downhole Qp profile at DTRA-SL2(C).

Surface Qs

Calculation of Q is highly sensitive to sources of noise (e.g., traffic) during acquisition.

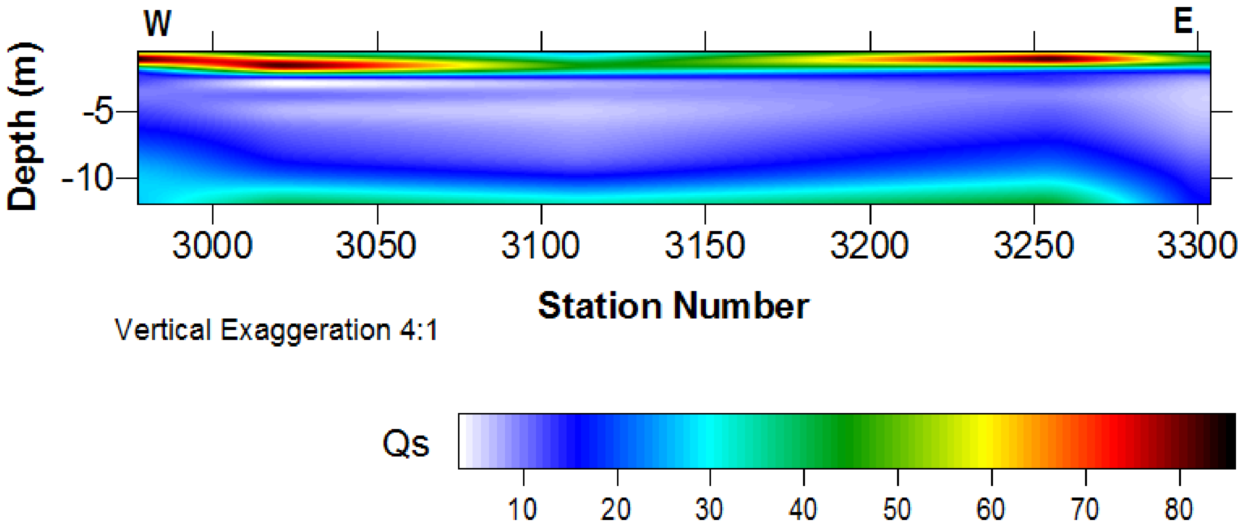


Figure 16: Surface Qs profile at DTRA-SL2(C).

Surface Qp

Calculation of Q is highly sensitive to sources of noise (e.g., traffic) during acquisition.

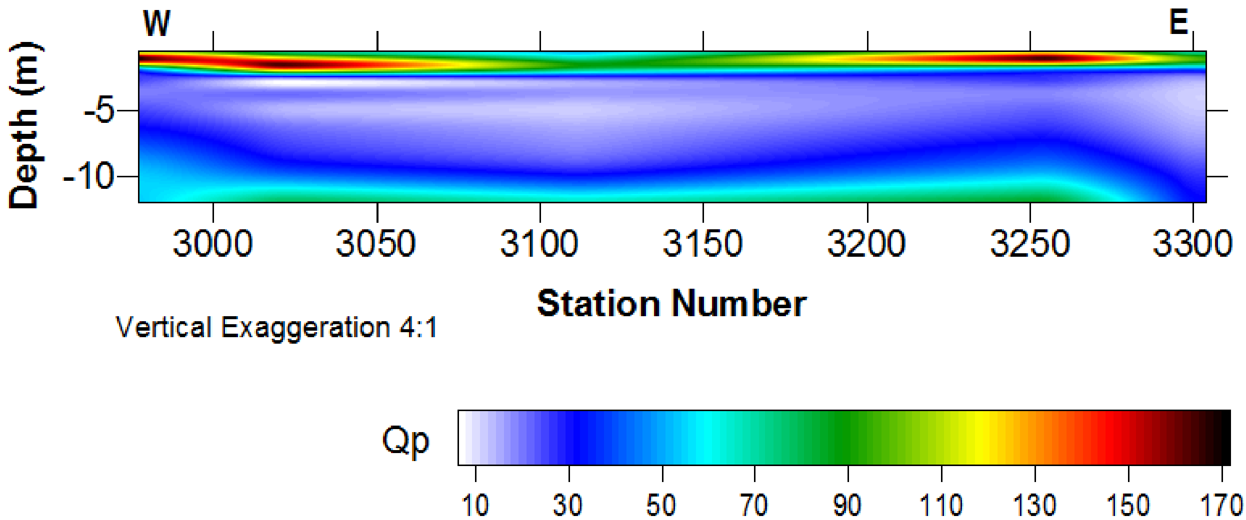


Figure 17: Surface Qp profile at DTRA-SL2(C).

Related Materials

Three compact discs will be shipped, along with hard copies of this report, which include digital copies of:

1. This report
2. PowerPoint presentation summarizing this report
3. Data files
4. Document explaining the data file format
5. Detailed list of deliverables

References

Di Siena, J.P., J.E. Gaiser, and D. Corrigan, 1984, Horizontal components and shear wave analysis of three component VSP data, in *Vertical Seismic Profiling, Part B: Advanced Concepts*, pp. 175-235, eds. M.N. Toksöz and R.R. Stewart, Geophysical Press, London.

Hasse, A.B. and R.R. Stewart, 2004, Attenuation estimates from VSP and log data: SEG expanded abstracts, 2497-2500.

Ivanov, J., R.D. Miller, J. Xia, J.B. Dunbar, and S. Peterie, 2010, Chapter 20: Refraction non-uniqueness studies at levee sites using the refraction-tomography and JARS methods: in Advances in Near-Surface Seismology and Ground-Penetrating Radar, SEG Geophysical Developments Series No. 15, R. D. Miller, J. D. Bradford, and K. Holliger, eds., Society of Exploration Geophysicists, 327-338.

Tonn, R., 1991, The determination of the seismic quality factor Q from VSP data: A comparison of different computational methods: *Geophysical Prospecting*, **39**, 1-27.

Xia, J., and R.D. Miller, 2010, Chapter 2: Estimation of near-surface shear-wave velocity and quality factor by inversion of high-frequency Rayleigh waves: in Advances in Near-Surface Seismology and Ground-Penetrating Radar, SEG Geophysical Developments Series No. 15, R. D. Miller, J. D. Bradford, and K. Holliger, eds., Society of Exploration Geophysicists, 17-36.

Xia, J., R.D. Miller, and C. B. Park, 1999, Estimation of near-surface velocity by inversion of Rayleigh waves: Geophysics, **64**, 691-700.