Final Report: Seismic Analysis at Strategic Border Sites
Trips 1 and 2: DTRA-C1

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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-C1 site.

Data Acquisition

Two lines of seismic data were acquired on January 24 and February 22, 2013, at DTRA-C1 coincident with the USGS ERT profiles (Figure 1). Lines 1000 and 6000 were approximately 400 m and 345 m long, respectively. 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 144-channel 3-component (3-C) land streamer with 48 stations separated by 1.2 m. Receivers were single 4.5 Hz and 40 Hz vertical geophones and two 14.5 Hz horizontal (SV orientation) geophones (Figure 3). Seismographs were a Geometrics Geode distributed system. The survey was fixed spread with variable 0-85.3 m source offset (Figure 4) to obtain sufficient seismic sampling within the depth of interest. Individual receiver spreads overlapped by one station. Multiple shots were acquired and recorded separately at each shot station and stacked during pre-processing to minimize ambient noise (Figure 5) and increase the signal-to-noise ratio.

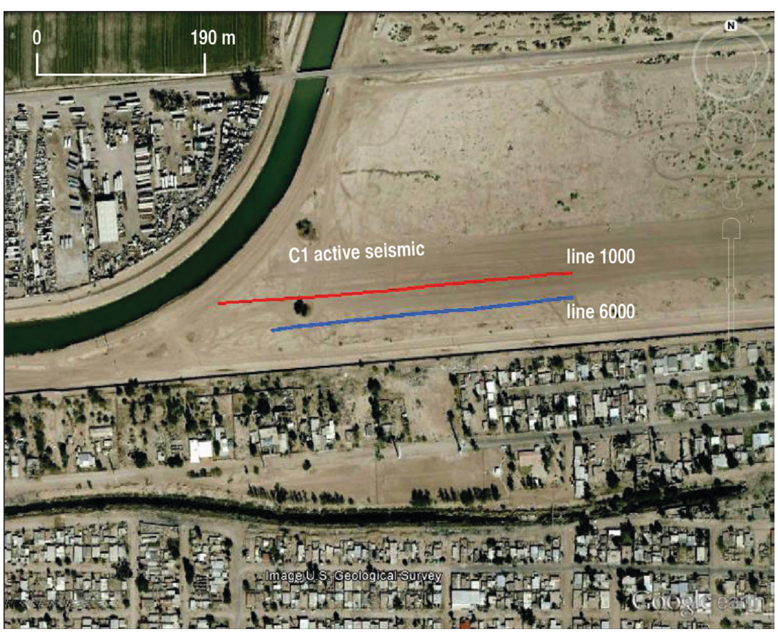


Figure 1: Aerial photo DTRA-C1 and locations of active seismic lines.

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

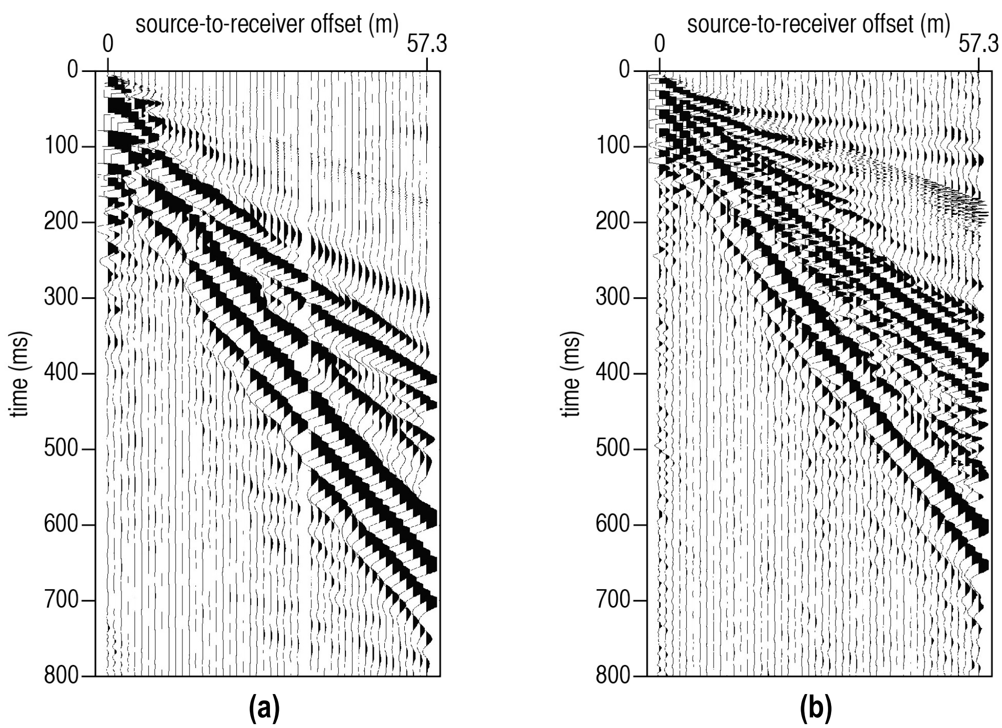


Figure 3: Representative off-end shot gathers at DTRA-C1. (*a*) Sledge hammer and shear block source recorded with shear 14.5 Hz geophones, SV orientation. (*b*) Weight-drop source recorded with vertical 40 Hz geophones.

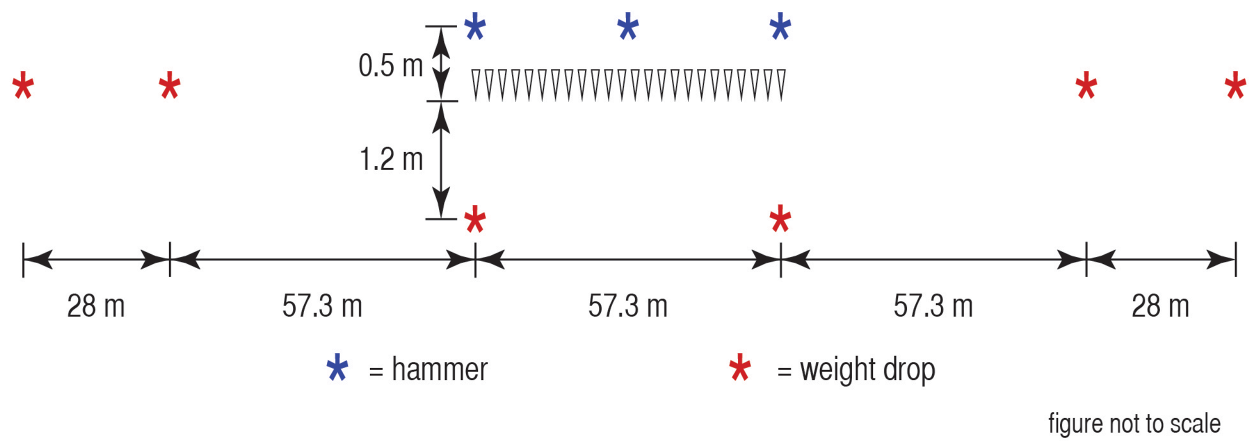


Figure 4: Diagram indicating all shot point locations relative to a single receiver spread. The receiver spread consisted of 48 stations separated by 1.2 m.

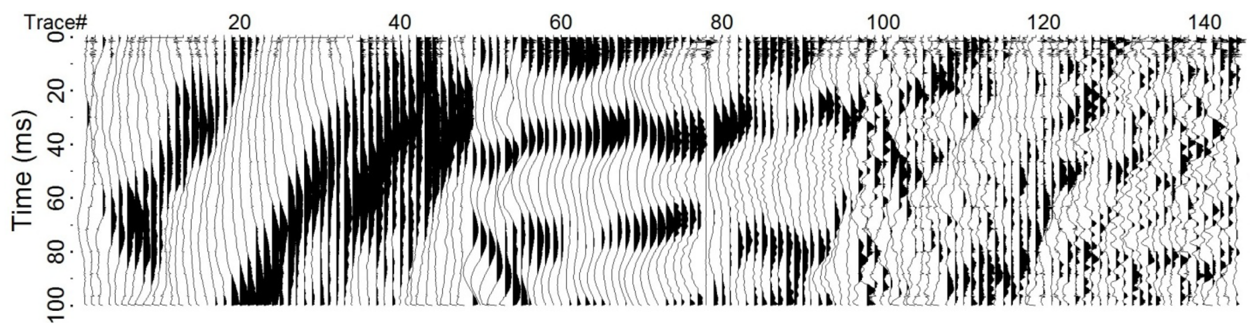


Figure 5: Representative ambient noise recorded at DTRA-C1. Traces 1-48 represent the 4.5 Hz geophones, 49-96 represent the shear geophones, and 97-144 represent the 40 Hz geophones.

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).

Note regarding refraction analysis: Some sites displayed evidence of a near-surface high-velocity layer (HVL). This signal was intermittent and did not extend to longer offsets and, therefore, was not considered in the analysis. Rather, first arrival interpretation followed an arrival pattern consistent with the "hidden" stratigraphic layer beneath the HVL. Acquisition and incorporation of borehole data will help to constrain the depth, thickness, and velocity of this HVL for each site, as needed.

Final Results

MASW

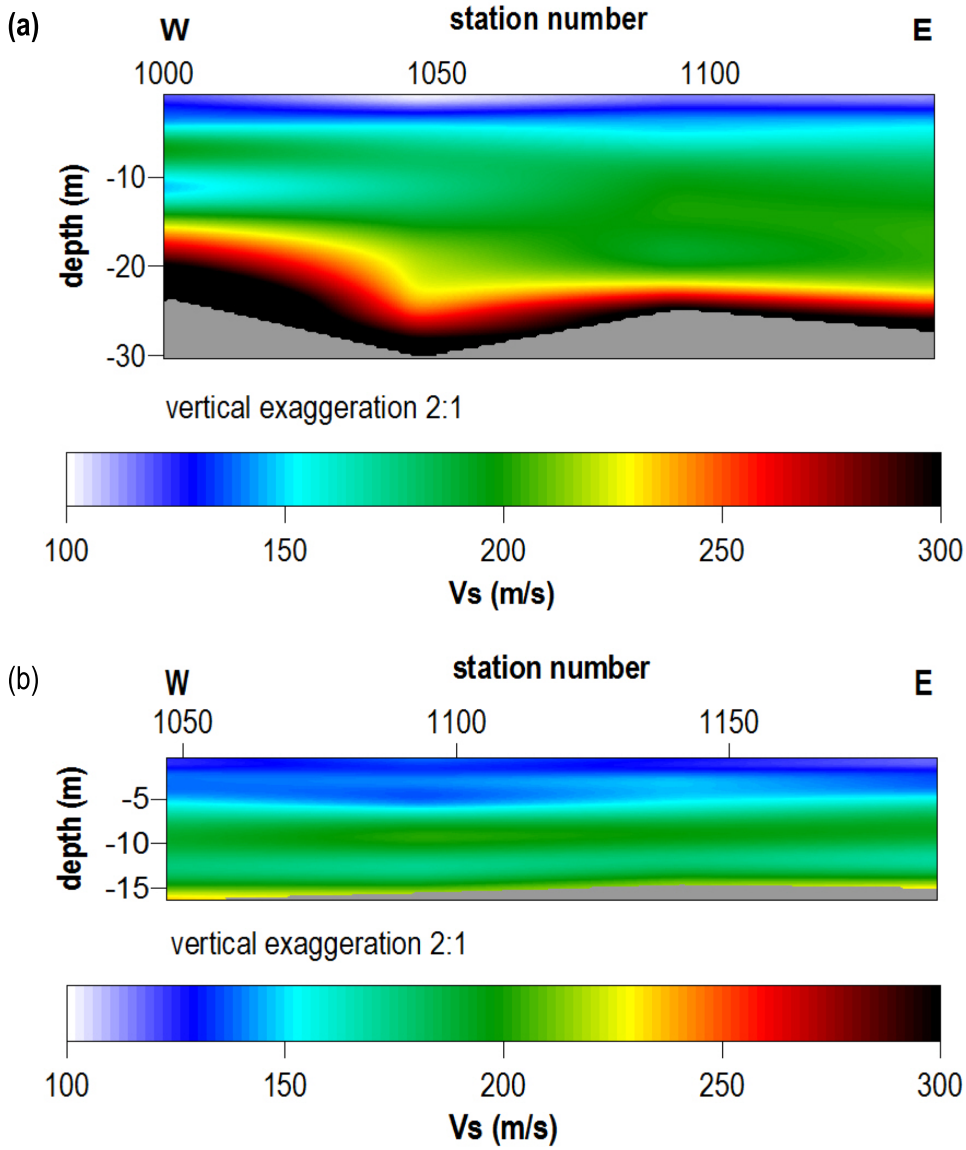


Figure 6: MASW Vs profiles from lines (*a*) 1000 and (*b*) 6000 at DTRA-C1. Gray represents areas with no data.

Vs Tomography

Although depth is limited, the Vs tomography results are consistent with the MASW profile. Due to low signal-to-noise at long offsets, the inversion loses ray coverage below 6 m. A stronger shear source (e.g., Vibroseis) would be required to reach greater depths with tomography methods at this site.

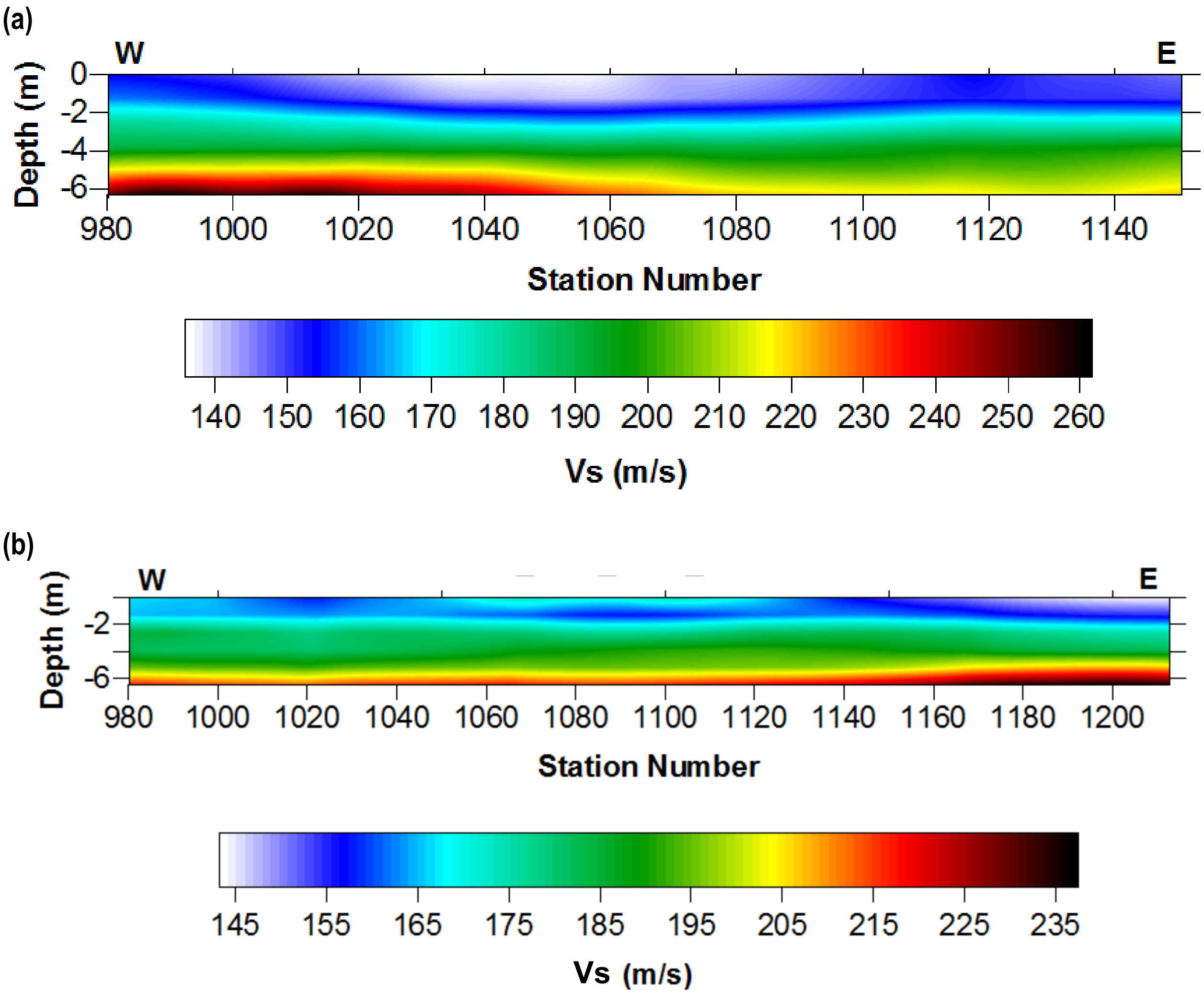
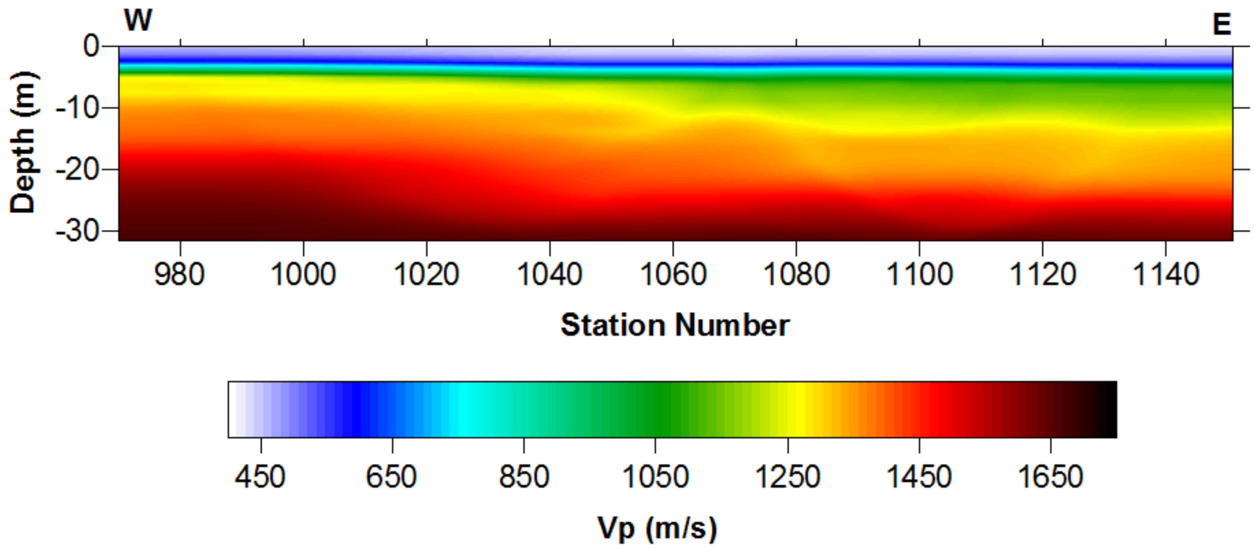


Figure 7: Vs tomography profiles from lines (*a*) 1000 and (*b*) 6000 at DTRA-C1. Vertical exaggeration of both profiles 3:1.

Vp Tomography

(a)



(b)

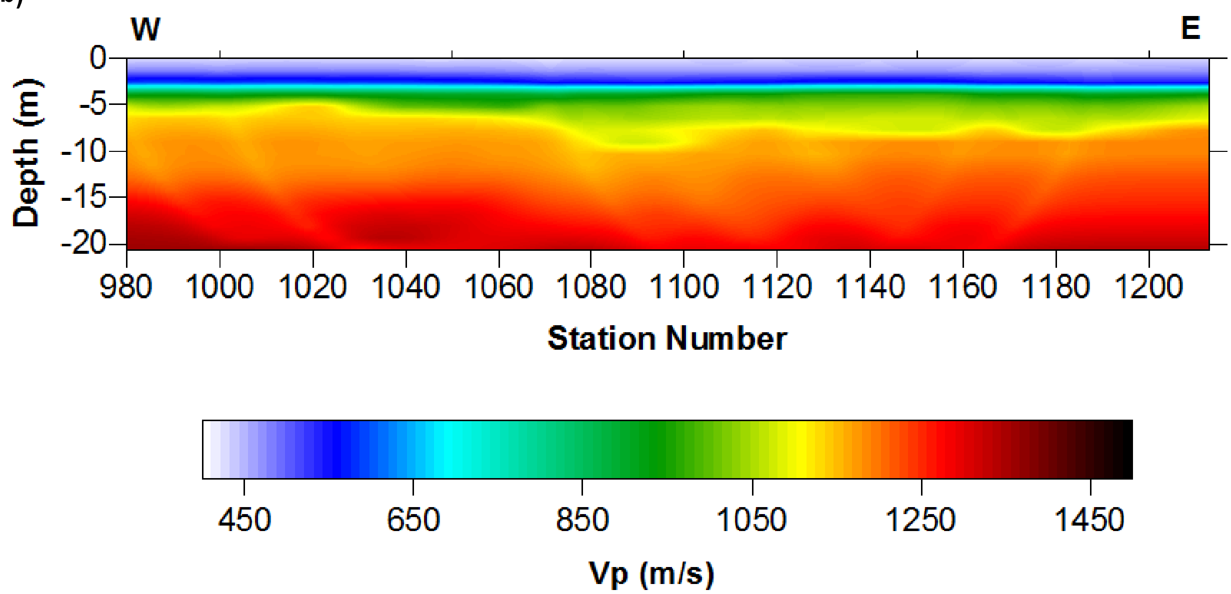


Figure 8: Vp tomography profiles from lines (*a*) 1000 and (*b*) 6000 at DTRA-C1. Vertical exaggeration in (*a*) is 1:1, while vertical exaggeration in (*b*) is 2:1.

Surface Qs

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

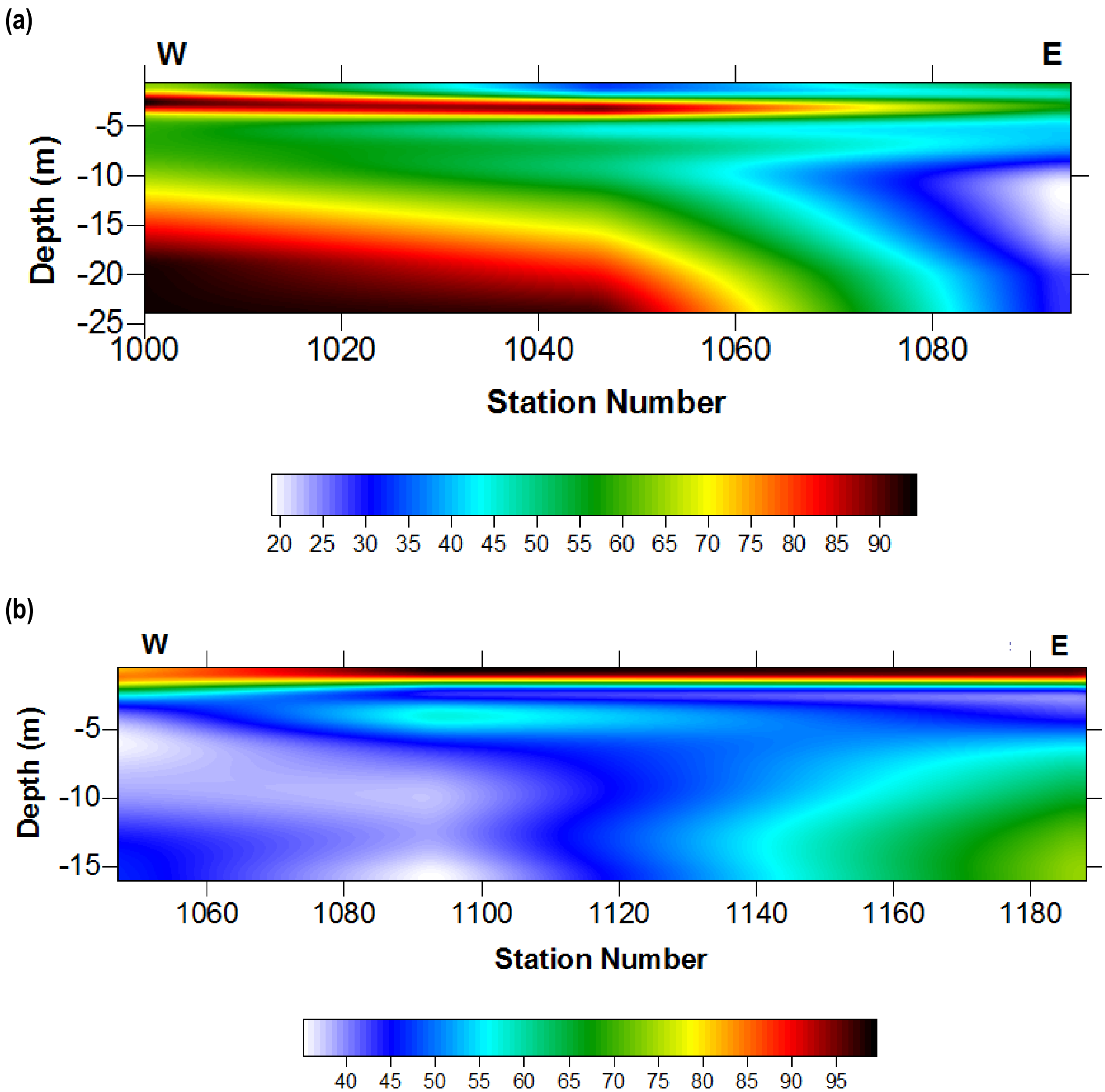
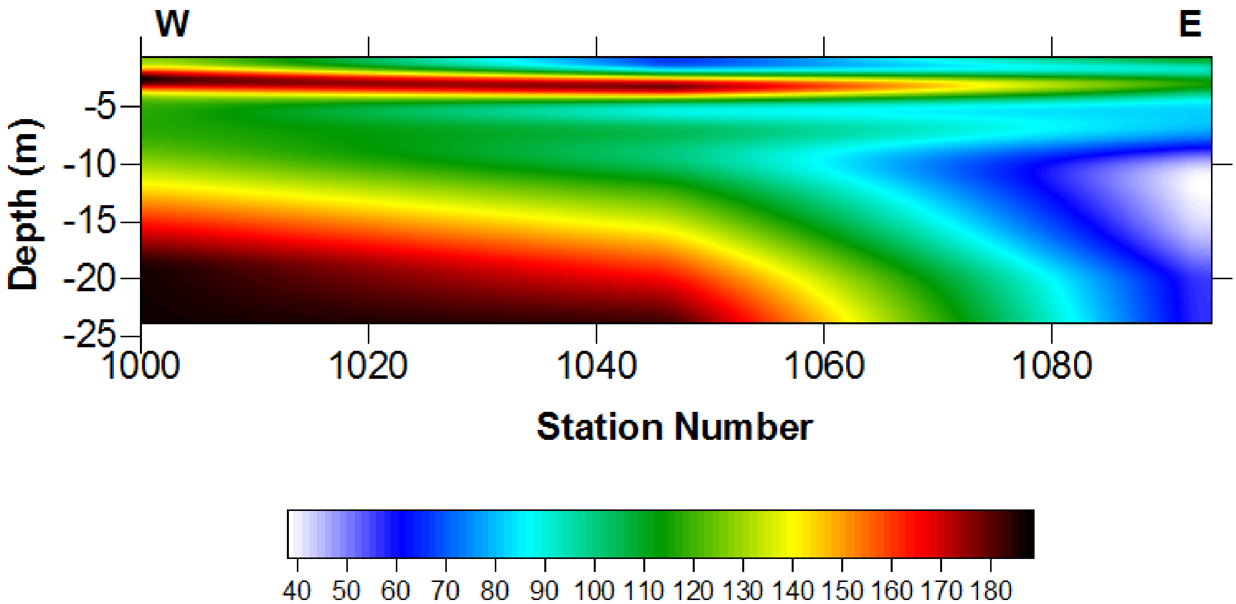


Figure 9: Surface Qs profiles from lines (a) 1000 and (b) 6000 at DTRA-C1.

Surface Qp

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

(a)



(b)

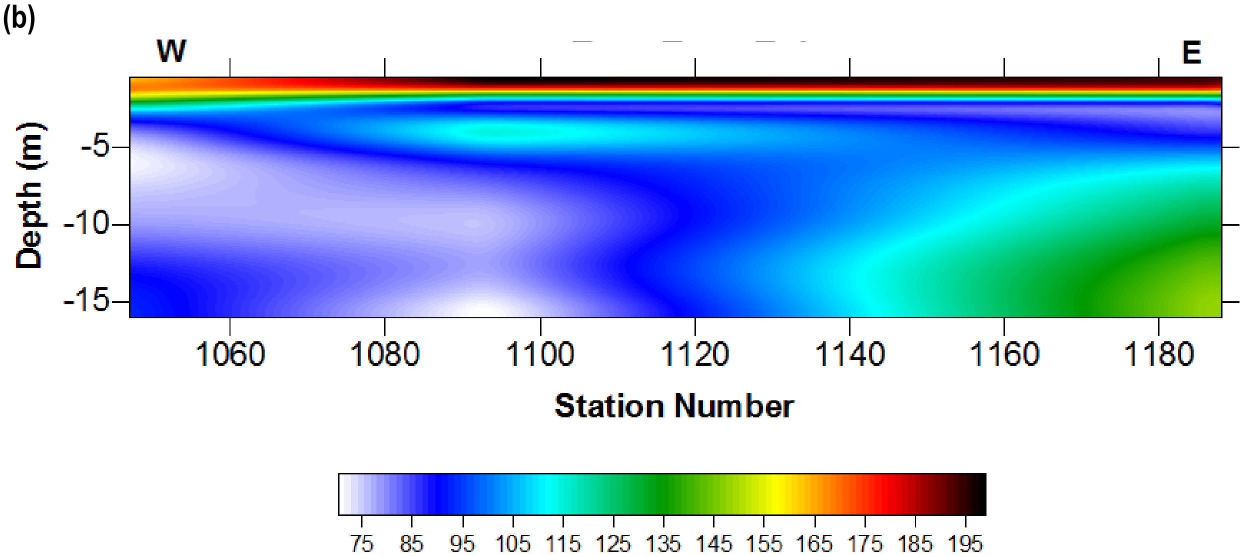


Figure 10: Surface Qp profiles from lines (*a*) 1000 and (*b*) 6000 at DTRA-C1.

Included Materials

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

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.

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.

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