

Final Report: Seismic Analysis at Strategic Border Sites Nog-E_N4 (DTRA N3)

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Final Report: Seismic Analysis at Strategic Border Sites Nog-E_N4 (DTRA N3)

Summary

The Kansas Geological Survey acquired borehole and surface seismic data at 15 DHS sites near the US-Mexico border. Surface seismic 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 (V_s), compressional-wave velocity (V_p), and seismic quality factor (Q_s and Q_p) for the near surface. Downhole data were processed to obtain downhole V_s , V_p , Q_s , and Q_p . This report contains final processing and results for Nog-E_N4 (DTRA N3).

Data Acquisition

One line of seismic data (~400 m) was acquired on February 25, 2013, at Nog-E_N4 (DTRA N3) 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 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.

Downhole data were acquired on January 23, 2014, approximately 70 m from the center of the surface seismic line, with a 3-C downhole Geostuff geophone (Figure 5). Receivers were located between depths of approximately 1.5 m and 29.7 m at approximately 0.75 m intervals (Figure 6). A repeatable shear and compressional 9 kg hammer source (Figure 7), developed and fabricated at the Kansas Geological Survey, was located at 3 m from the borehole. 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.

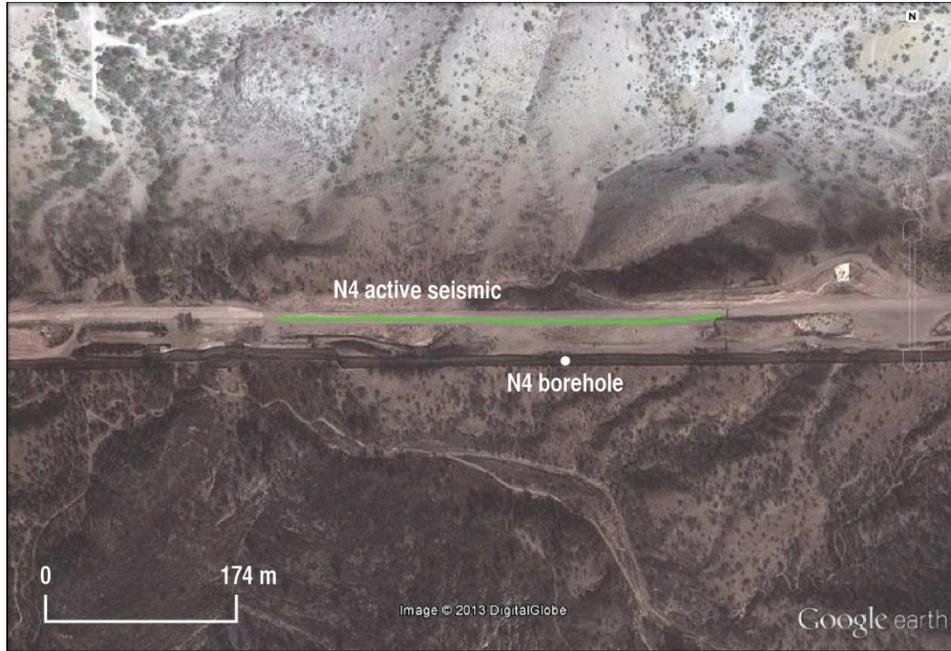


Figure 1: Aerial photo of Nog-E_N4 (DTRA N3) and location of the active seismic line.



Figure 2: ASI with 144-channel 3-C land streamer, detached.

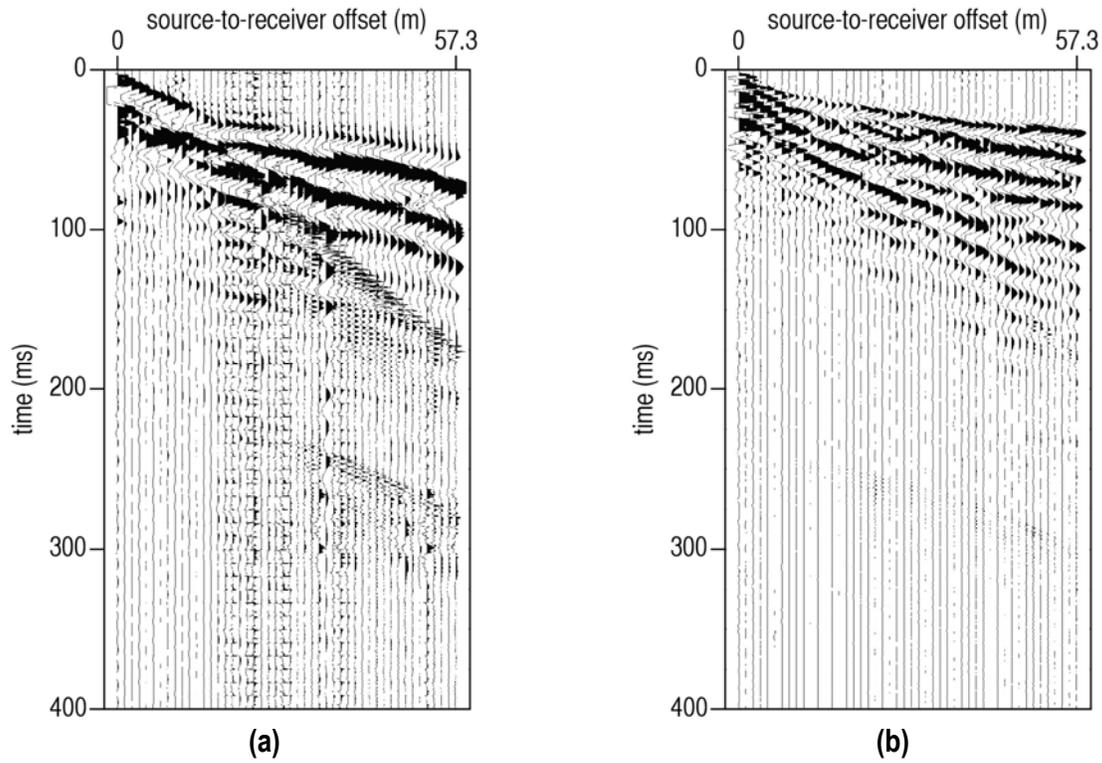


Figure 3: Representative off-end shot gathers at Nog-E_N4 (DTRA N3). (a) Sledge hammer and shear block source recorded with shear 14.5 Hz geophones, SV orientation. (b) Weight-drop source recorded with vertical 40 Hz geophones.

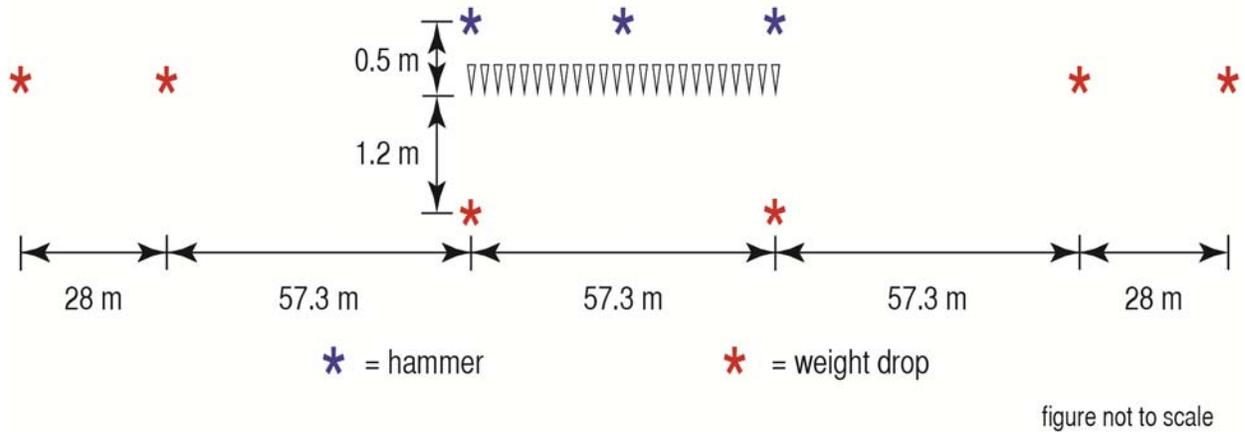


Figure 4: Diagram indicating all shot point locations relative to a single receiver spread. The receiver spread consisted of 48 stations separated by 1.2 m.

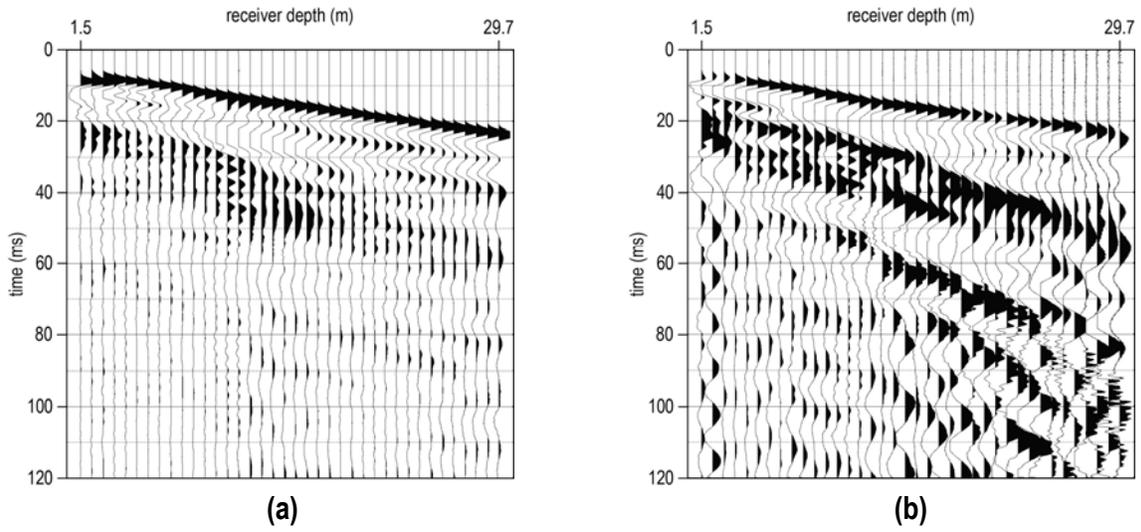


Figure 5: Representative unprocessed downhole (a) vertical and (b) shear records at Nog-E_N4 (DTRA N3).

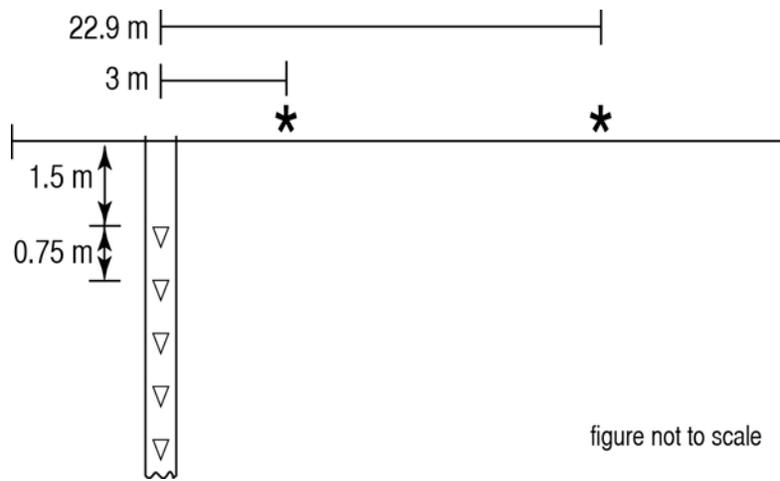


Figure 6: Downhole seismic field layout.



Figure 7: Downhole seismic acquisition at Nog-E_N4 (DTRA N3).

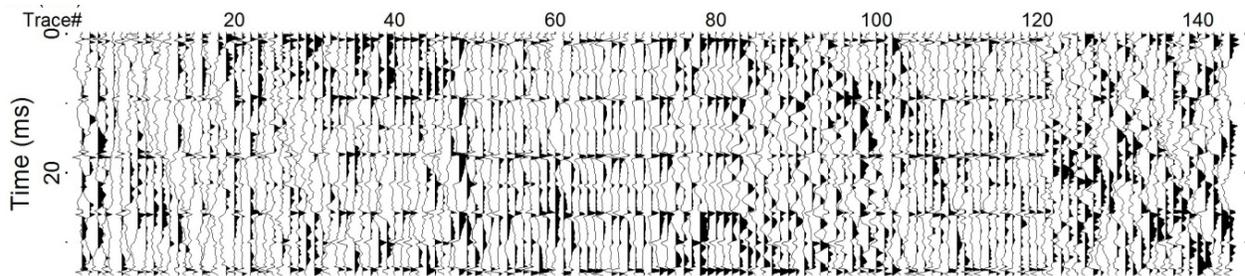


Figure 8: Representative ambient noise recorded at Nog-E_N4 (DTRA N3). Traces 1-48 represent the 4.5 Hz geophones, 49-96 represent the shear geophones, and 97-144 represent the 40 Hz geophones.

Data Processing

Multichannel-analysis of surface waves (MASW) was used to analyze dispersive Rayleigh-wave energy and estimate shear-wave velocity (V_s). Fundamental-mode energy was interpreted and inverted using a weighted, damped least-squares approach (Xia et al., 1999), resulting in a 2-D V_s profile. Average and interval downhole compressional-wave velocity (V_p) and V_s 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. Refraction tomography with 1.2 x 1.2 m cell size was used to estimate V_s and V_p . 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 V_s and V_p profiles. Shear- and compressional-wave seismic quality factors (Q_s and Q_p , respectively) were obtained using a surface wave inversion technique (Xia et al., 2010). Downhole shear records were numerically rotated to orient the recorded shear-wave traces in the vertical (SV) and horizontal (SH) polarization directions (Di Siena et al., 1984). The direct P-waves and S-waves were isolated on compressional and shear records, respectively, and the spectral ratio method was used to estimate Q_p and Q_s 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

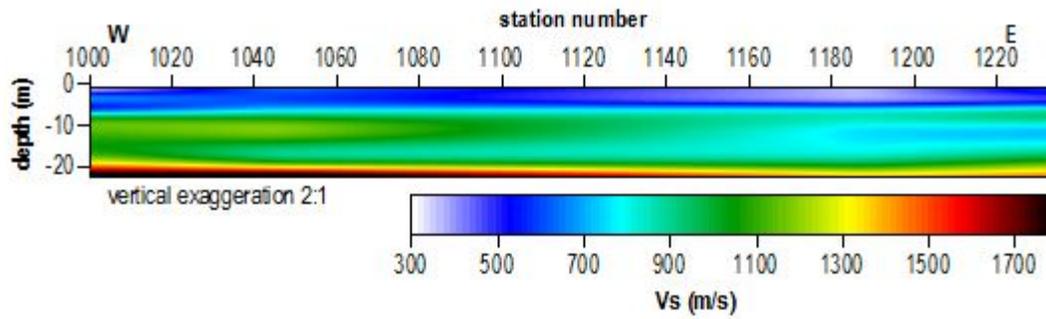


Figure 9: MASW V_s at Nog-E_N4 (DTRA N3).

Downhole Vs

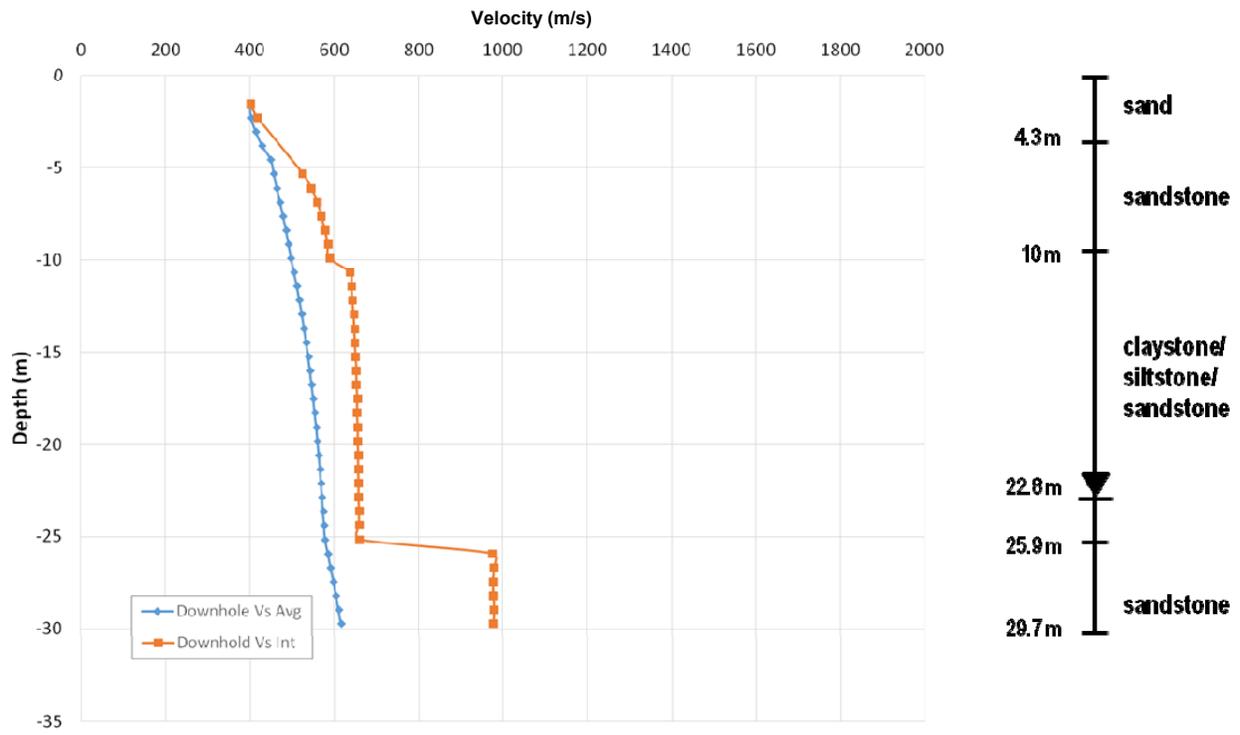


Figure 10: Downhole Vs profile at Nog-E_N4 (DTRA N3).

Downhole Vp

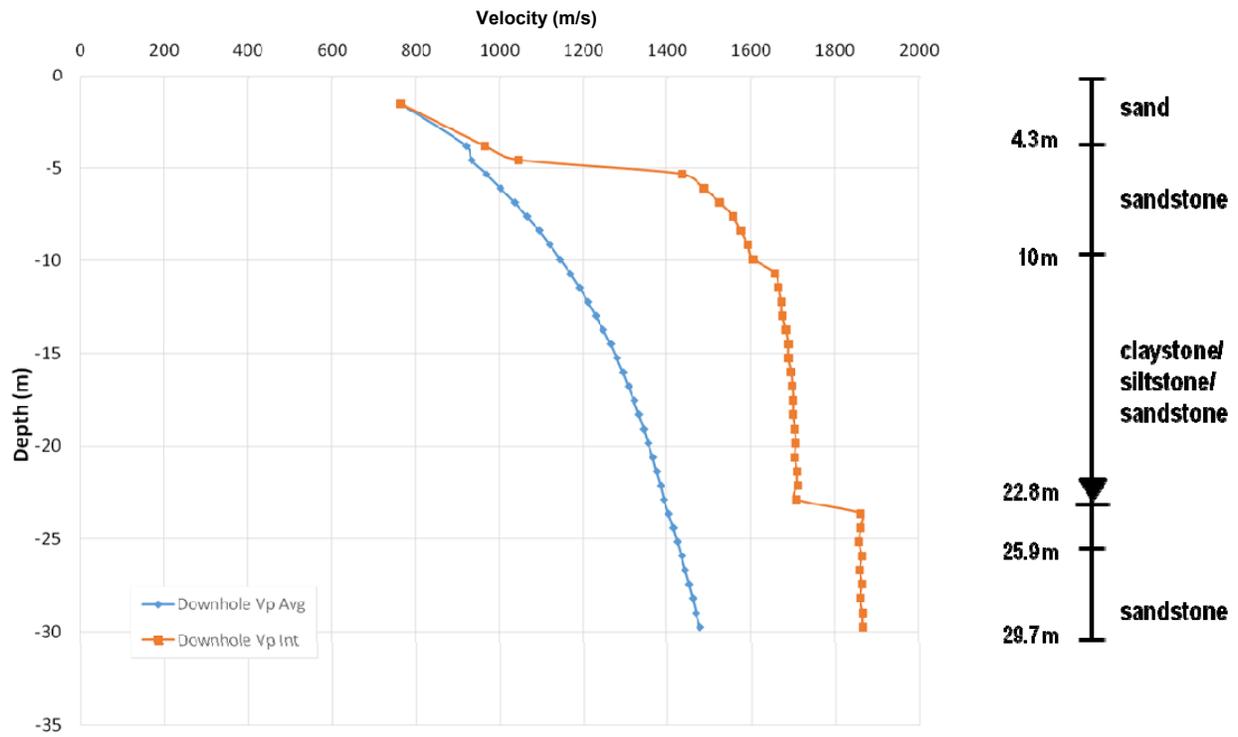


Figure 11: Downhole Vp profile at Nog-E_N4 (DTRA N3).

Vs Tomography

A smoothed version of the final MASW Vs profile with the velocity inversion removed was used as the initial model. Information from downhole seismic data improved discrimination of shear waves from mode-converted seismic energy. Shot records were re-picked to ensure accurate arrival times of the direct and refracted shear waves.

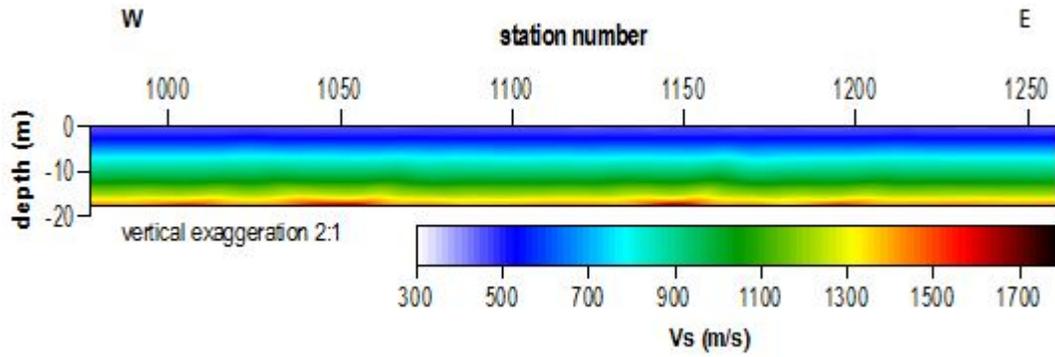


Figure 12: Vs tomography at Nog-E_N4 (DTRA N3).

Vp Tomography

A scaled, smoothed version of the final MASW Vs profile with the velocity inversion removed was used as the initial model. Picked first arrival times used for preliminary processing were reviewed to confirm their accuracy and used for final processing.

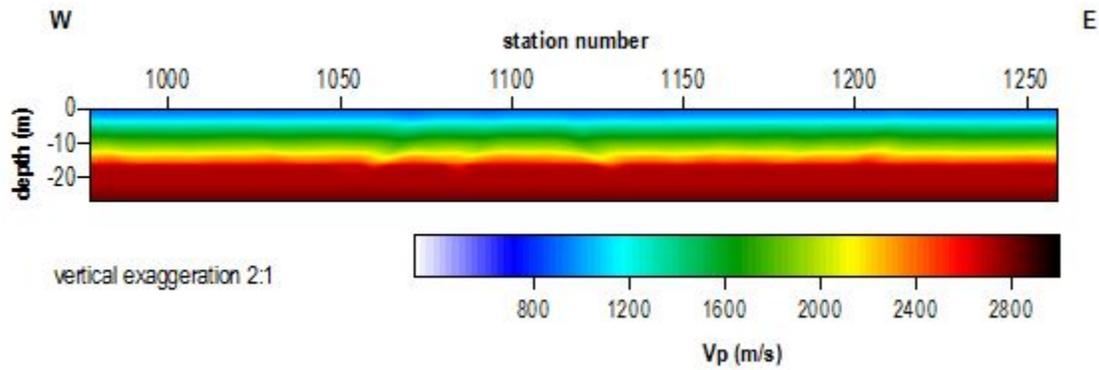


Figure 13: Vp tomography at Nog-E_N4 (DTRA N3).

Downhole Q_s

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

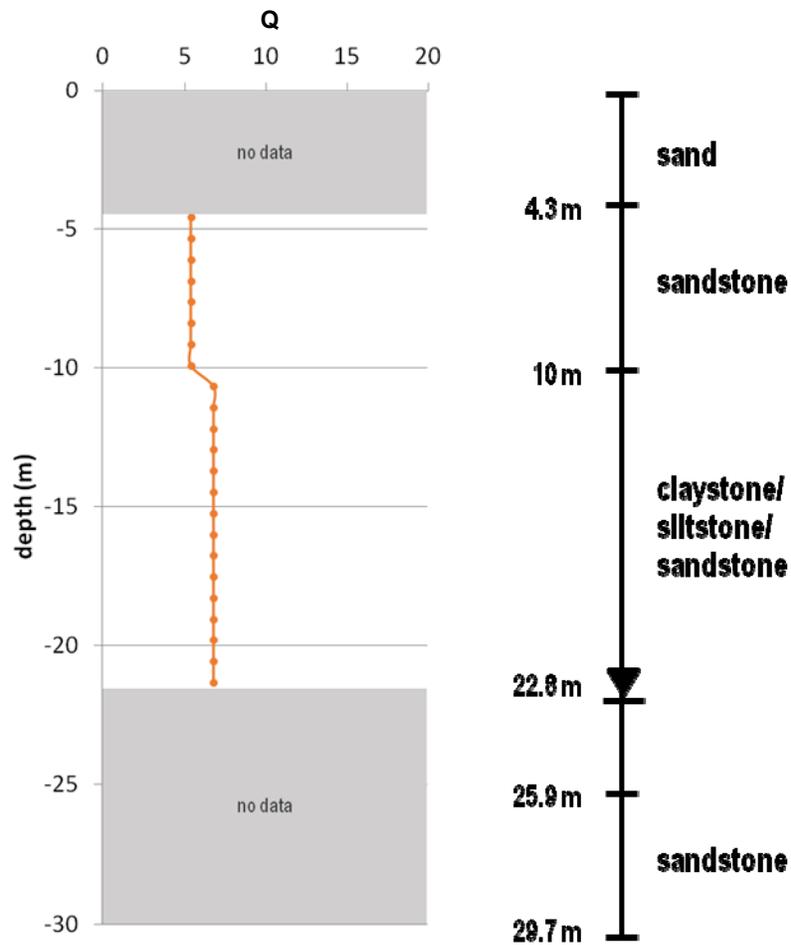


Figure 14: Downhole Q_s profile at Nog-E_N4 (DTRA N3).

Downhole Q_p

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

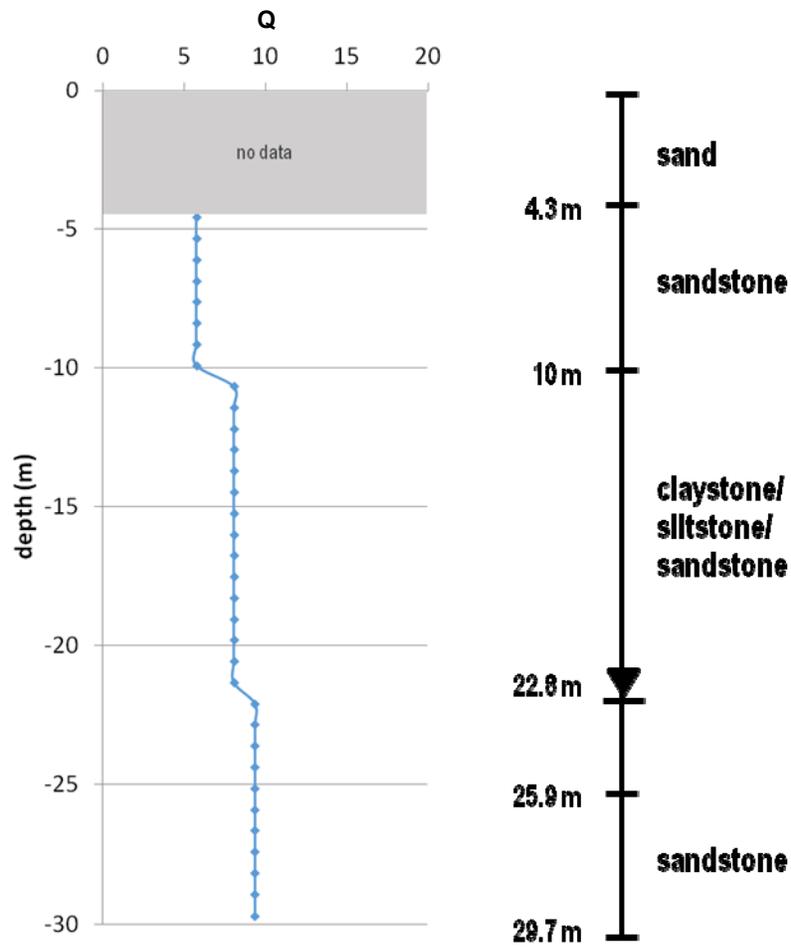


Figure 15: Downhole Q_p profile at Nog-E_N4 (DTRA N3).

Surface Q_s

Calculation of Q is highly sensitive to sources of noise (e.g., traffic) during acquisition. Due to lack of stability in the inversion, the upper 6 m is low confidence.

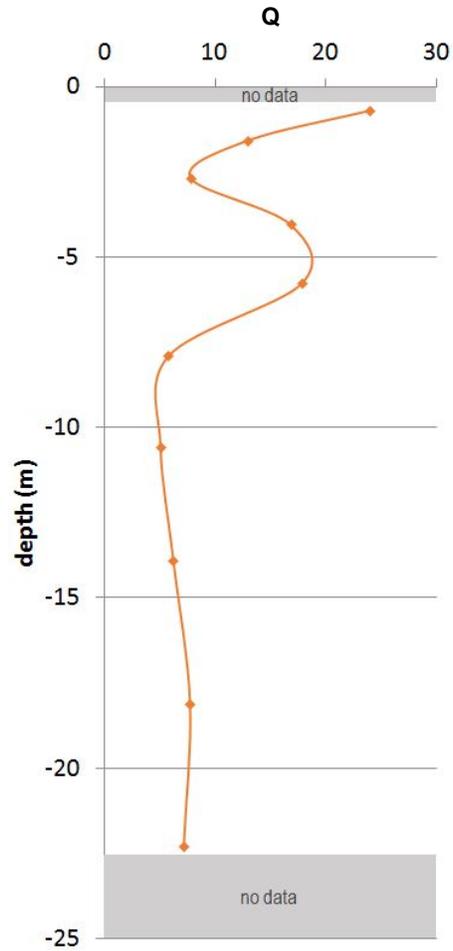


Figure 16: Surface Q_s at Nog-E_N4 (DTRA N3).

Surface Q_p

Calculation of Q is highly sensitive to sources of noise (e.g., traffic) during acquisition. Due to lack of stability in the inversion, the upper 6 m is low confidence.

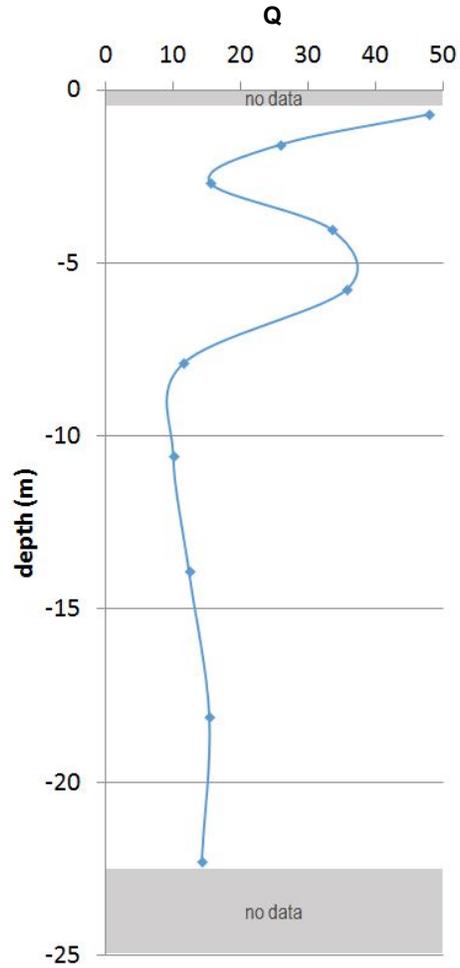


Figure 17: Surface Q_p profiles at Nog-E_N4 (DTRA N3).

Related Materials

Delivered materials include:

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

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