geoconvention
Calgary • Canada • May 13-17 2019

Integrated anisotropic model building for the Montney using sonic and hybrid cable DAS VSP

Scott Leaney,Theo Cuny,Edgar Arteaga,Takashi Mizuno, Schlumberger; Marco Perez,Velvet

Summary

Sonic anisotropy is integrated with multi-offset hybrid DAS VSP data to build and calibrate a VTI velocity model. The initial VTI model from sonic is cross-validated against microseismic data and calibrated to direct P times from the hybrid multi-offset VSP data set. The resulting model aids in quantitative interpretation and provides a starting point for a future depth imaging project.

Introduction

In the spring of 2018, vertical, deviated and lateral wells were drilled from a platform in Western Alberta for targets in the Montney. Microseismic downhole monitoring was done in the deviated well with a downhole array (VSI-20) tool deployed on a wireline (Nova-F) cable equipped with single mode optical fiber. Thirty magnetic clamps were also deployed along the cable to assure good acoustic coupling of the fiber in the most vertical sections of the well. After microseismic monitoring was complete, twelve vibroseis points were acquired along a road to provide a multi-offset VSP data set. The DAS (distributed acoustic sensing) VSP waveform data quality was generally good, providing direct times for model calibration and clear reflections for imaging. Times from the clamped downhole array were also used for anisotropic model calibration.

Prior to the microseismic monitoring and multi-offset VSP, full waveform sonic (Sonic Scanner) data were acquired in the vertical pilot well and in the deviated monitoring well. Advanced sonic processing was applied, including dispersive slowness fitting of crossed-dipole and low frequency monopole Stoneley waveforms. Such processing provides a subset of anisotropy parameters from which an upscaled layered anisotropic model can be built. Model scales are chosen based on the frequency of application, higher for microseismic, intermediate for seismic reflection simulation and lower for seismic imaging. In what follows examples will be shown of VTI model building from sonic, with calibration using hybrid VSP times.

Workflow and results

Sonic data from the vertical and deviated wells were processed using dispersive slowness estimation and radial profiling inversion. For an overview of these techniques applied to a case study see Sinha et al., 2006. We focus here on results from the vertical well. In a vertical well sonic processing provides compressional slowness (modulus c33), fast and slow shear slownesses (moduli c44 and c55) and horizontal shear slowness from the Stoneley (modulus c66). From these four measurements, Bayesian sonic tensor completion (Leaney and Jocker, 2018) is used to complete an orthorhombic tensor corresponding to a vertically fractured VTI (FVTI) medium. The sonic fast shear azimuth provides a depth-dependent symmetry axis rotation angle, resulting in logs of monoclinic moduli. Such logs can be upscaled for AVAz simulation (Leaney et al., 2019). In this study we determine, from the FVTI moduli, the nearest VTI medium at every depth and carry these logs forward into upscaling and model building.

Figure 1 shows sonic VTI logs and several upscaled models. Properties for the upper 500m came from the fiber VSP times and data base Vp correlations, merged with the sonic scale VTI logs. The models shown have been built following the scattering or reflection criterion and the transmission citerion of Liner and Fei (2007). These 50Hz models were calibrated to the multi-offset VSP times using travetime inversion. Another model was also built from the sonic VTI logs for microseismic processing. It comes from a 100Hz transmission criterion to derive minimum layer thickness and smoothing kernel length. Figure 2 shows the microseismic model, direct P, Sh and Sv (PHV) rays and PHV times plotted on waveforms of a microseismic event. This model reproduced sleeve event locations very well and required very little VTI calibration (Mizuno et al., 2010) providing independent validation of the sonic tensor completion technique.

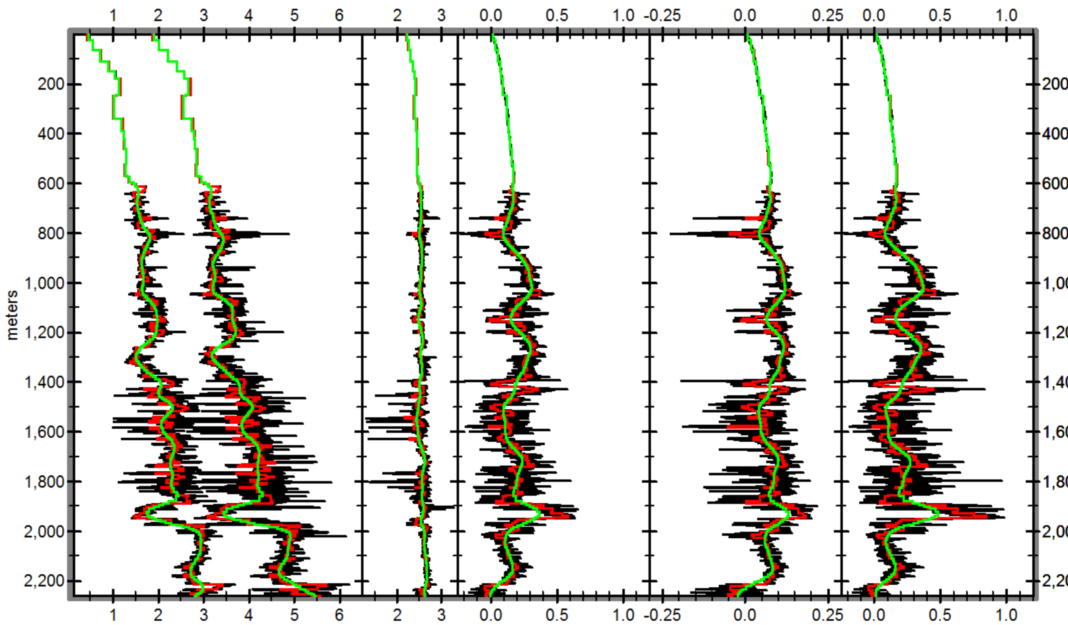

Figure 1. Sonic-derived VTI logs (black), 50Hz upscaled reflection model (red) and upscaled migration model (green). Left to right: Vs, Vp, density, epsilon, delta, gamma.

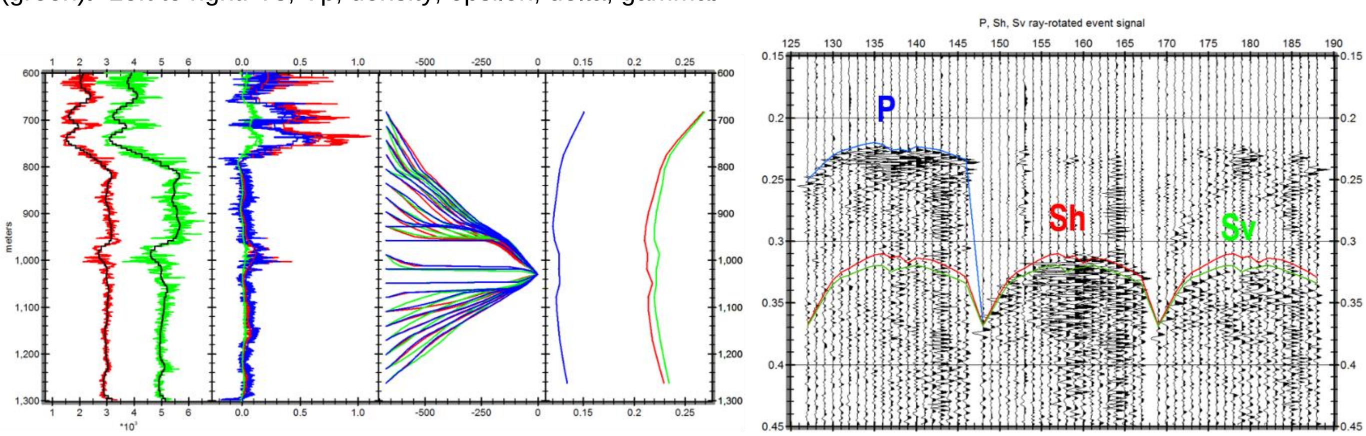

Figure 2. VTI logs and 100Hz upscaled transmission model for microseismic (left). P, Sh and Sv rays, times. Right: receiver ray polarization -rotated waveforms for a microseismic event with sonic VTI model times overlain.

Figure 3 shows one of the DAS offset VSPs, with 10m and optimized variable gauge length reprocessing of the optical data. (Schlumberger's hDVS = heterodyne Distributed Vibration Sensing system allows for variable gauge length processing). Times are easily picked and reflections are clearly visible. DAS systems contain wavenumber filters due to pulse length averaging and gauge length differencing, and some systems also contain a digital phase estimation operation, so wavenumber deconvolution is needed prior to some processing and imaging steps. This work is ongoing. Here we concentrate on VTI model calibration using multi-offset direct P times

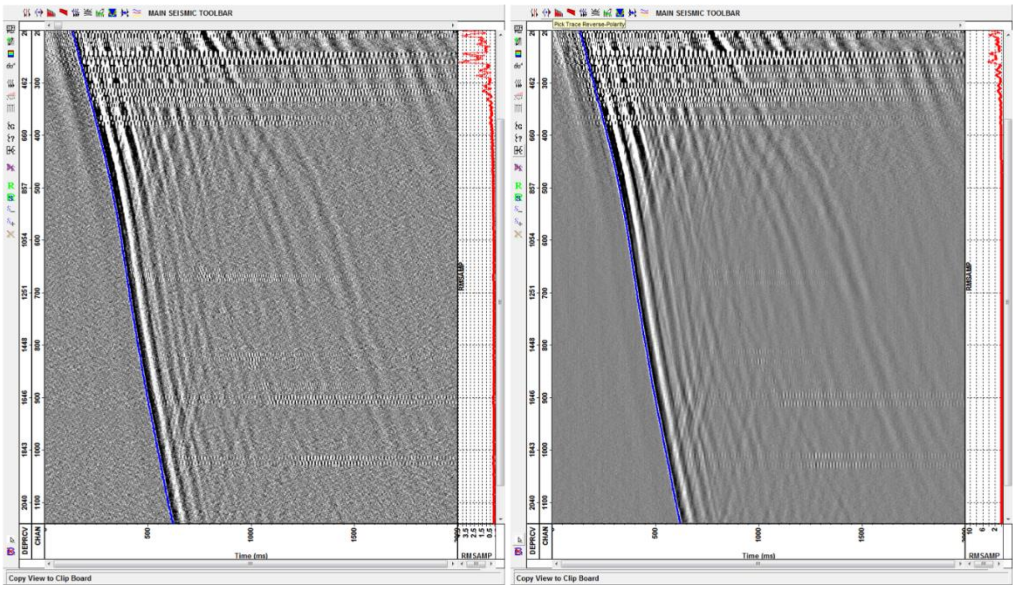

Figure 3. DAS VSP data for the nearest offset shot. Left; 10m gauge length, right: optimized variable gauge length.

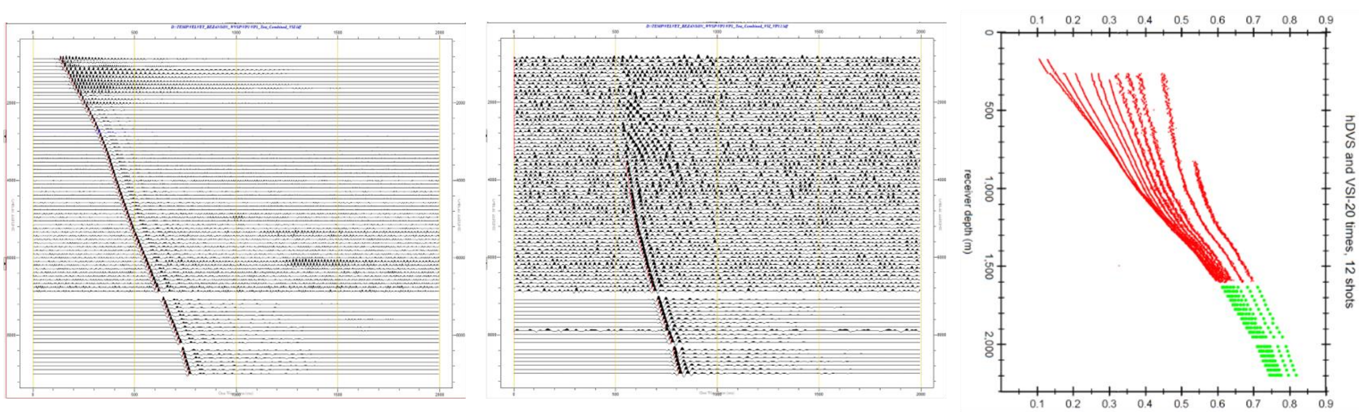

Figure 4. DAS VSP decimated by 15 with clamped geophone Z-axis data (bottom 19 traces). Left: near offset shot, middle: far offset shot. Right: direct P time picks versus receiver depth for DAS receivers (red0 and VSI receivers (green).

Figure 4 shows decimated DAS VSP data decimated every 15th trace after geophone transformation with the clamped geophone Z-axis VSI data illustrating consistent timing and waveforms. Also shown are the direct P time picks versus receiver depth for all 12 offsets. These times will be used to calibrate the initial VTI models shown in Figure 1.

Acknowledgements

We gratefull acknowledge Velvet Resources Inc. and Schlumberger for permission to present this work.

References

Chapman, C.H., 2004, Fundamentals of seismic wave propagation, Cambridge University Press.

Leaney, W.S. and Jocker, J., 2018, Sonic tensor completion, Geoconvention 2018.

Leaney, W.S. and Jocker, J., 2018, Sonic tensor completion and applications, Society of Exploration Geophysicsts Expanded Abstracts.

Leaney, S., Arteaga, E., Lawton, D. and Innanen, K., 2019, Sonic anisotropy and monoclinic modelling at the CaMI site, Geoconvention 2019, submitted.

Liner, C. and Fei, T., 2007, The Backus number, The Leading Edge, April, 420-426.

Schoenberg, M., and Sayers, C., 1996, Introducing ANNIE: A simple three-parameter anisotropic velocity model for shales, Journal of Seismic Exploration, 5, 35-49.

Sinha, B.K., Vissapragada, B., Renlie, L. and Tysse, S., 2006, Radial profiling of the three formation shear moduli and its application to well completions: *Geophysics*, **71**, No. 6, E65-E77.