S-WAVE SPLITTING ANALYSIS OF 4-C VSP IN ALTAMONT-BLUEBELL FIELD

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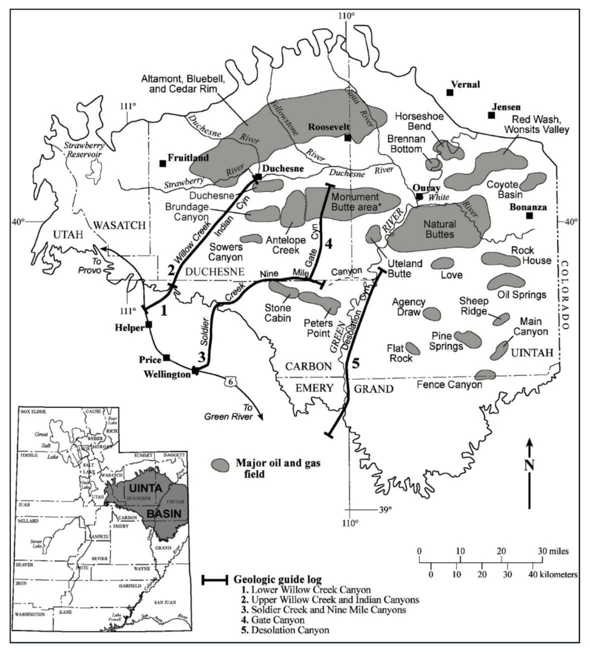
Abstract

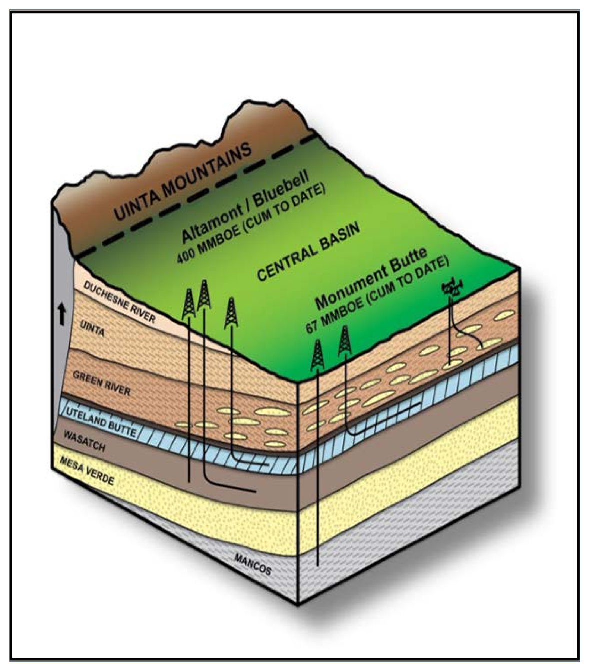
Within the Altamont-Bluebell survey, multiple VSP datasets were acquired. The first dataset was a conventional zero-offset VSP. The second dataset was six shots of offset VSPs. The objective of those shots was to estimate VTI Thomsen parameters to aid with 3D processing of seismic data, and also to create a HTI model for fracture characterization of the reservoirs. However, these offset VSPs were limited in terms of depth, offset, and azimuthal coverage, and walkaway VSPs would have been a better choice for such an objective, but certainly more expensive. The third dataset was a 4-component VSP. Its objective is S-wave splitting analysis for fracture characterization of the reservoirs.

In this paper, we began with the raw field data, applied processing, including some twists in order to use surface seismic methods of AVAZ and VVAZ on VSP data, which resulted in final products of azimuthal anisotropy intensity and orientation parameters. Offset VSPs were processed through the VSP-CDP transform, then AVAZ analysis was applied. A VVAZ workflow is developed here for offset, walkaround, or walkaway VSPs using a method for surface seismic, and interval anisotropy properties are calculated for each receiver. For AVAZ and VVAZ, deeper levels including the deeper target of Wasatch-180 are more reliable because of better coverage. S-wave analysis is carried out using Alford (1986) 4-C rotation to separate fast and slow modes. This method assumes that the symmetry axis is vertically invariant. To overcome this assumption, a layer stripping technique was applied using Winterstien and Meadows (1991).

Altamont-Bluebell Field

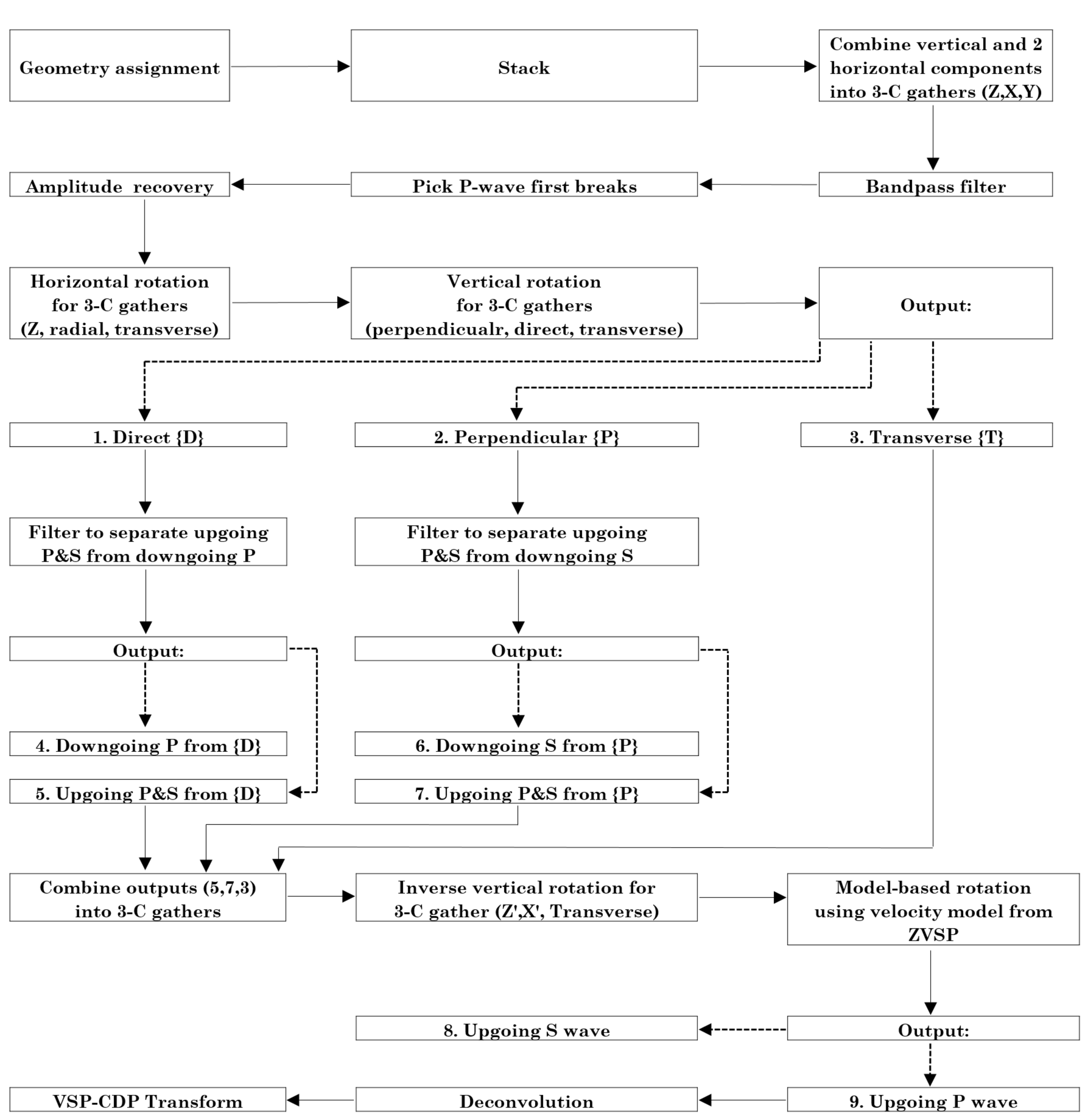


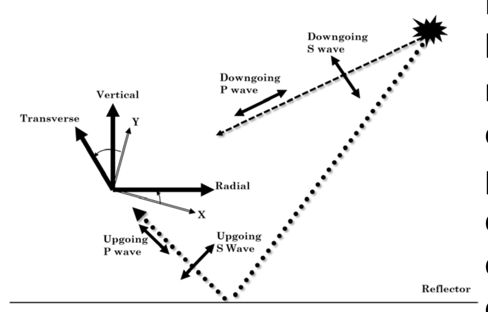
Location of Uinta basin, Utah (bottom left) and major oil and gas fields within Uinta basin (after Morgan, 2003).



Uinta Basin, Utah. Altamont-Bluebell field is the northern central part of the basin, and Bluebell is the eastern part of Altamont-Bluebell Field. Three main targets are: Upper Green River, Lower Green River (Uteland Butte and Castle Peak), and Wastach formations. Courtesy of: Newfield.

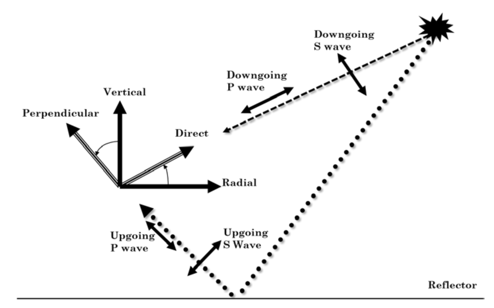
Processing Workflow



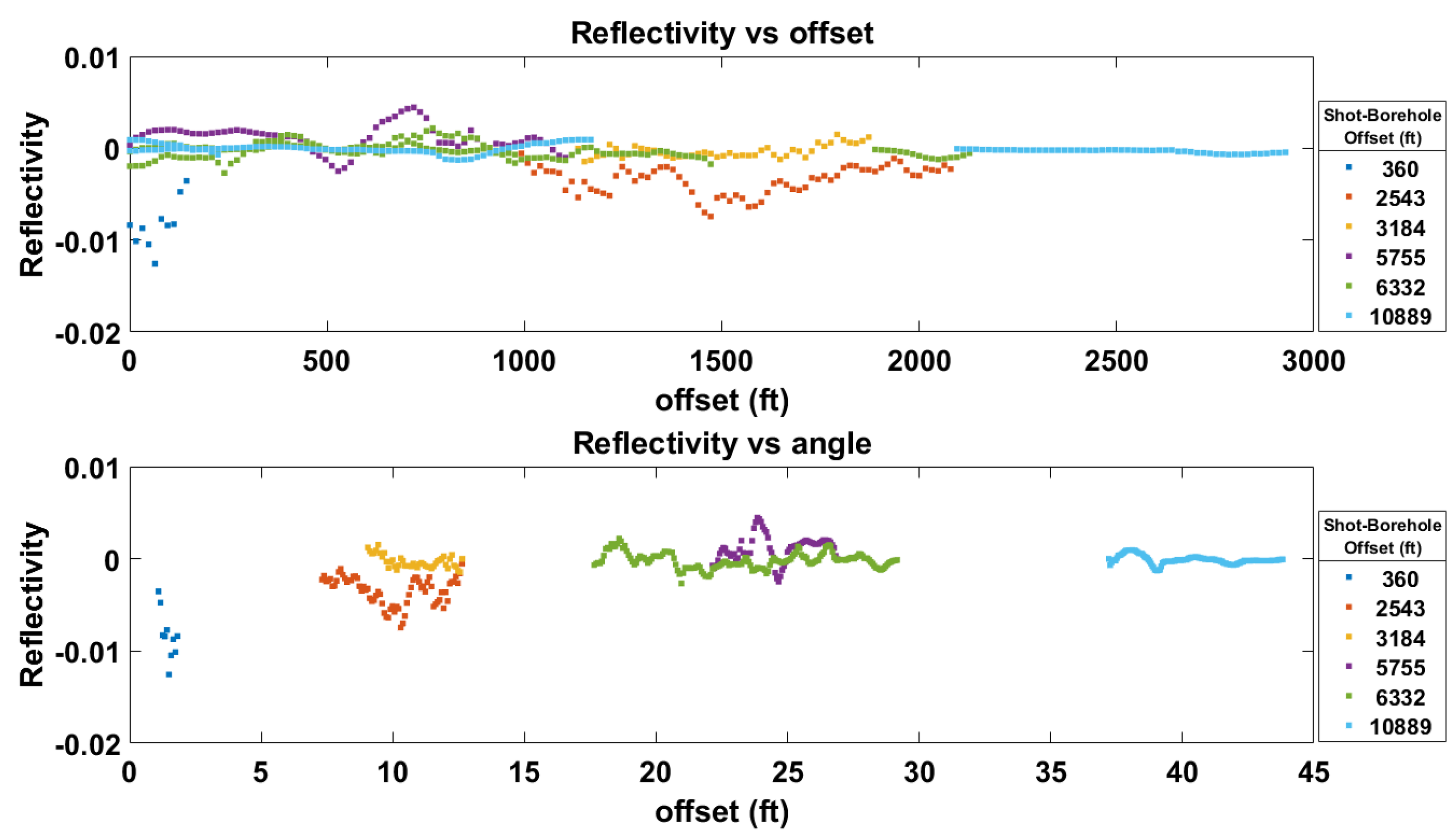


Horizontal rotation. After horizontal orientation, radial component is oriented at the propagation plane and contains most of the energy between horizontal components.

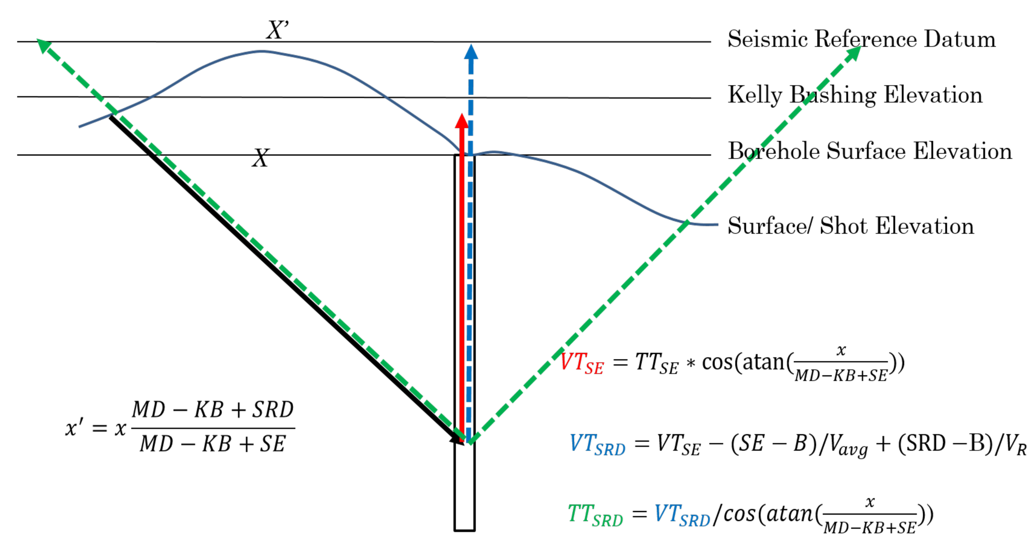
Vertical rotation. After vertical orientation, direct component is oriented towards the source and contains most of the downgoing P-wave energy.



Analysis

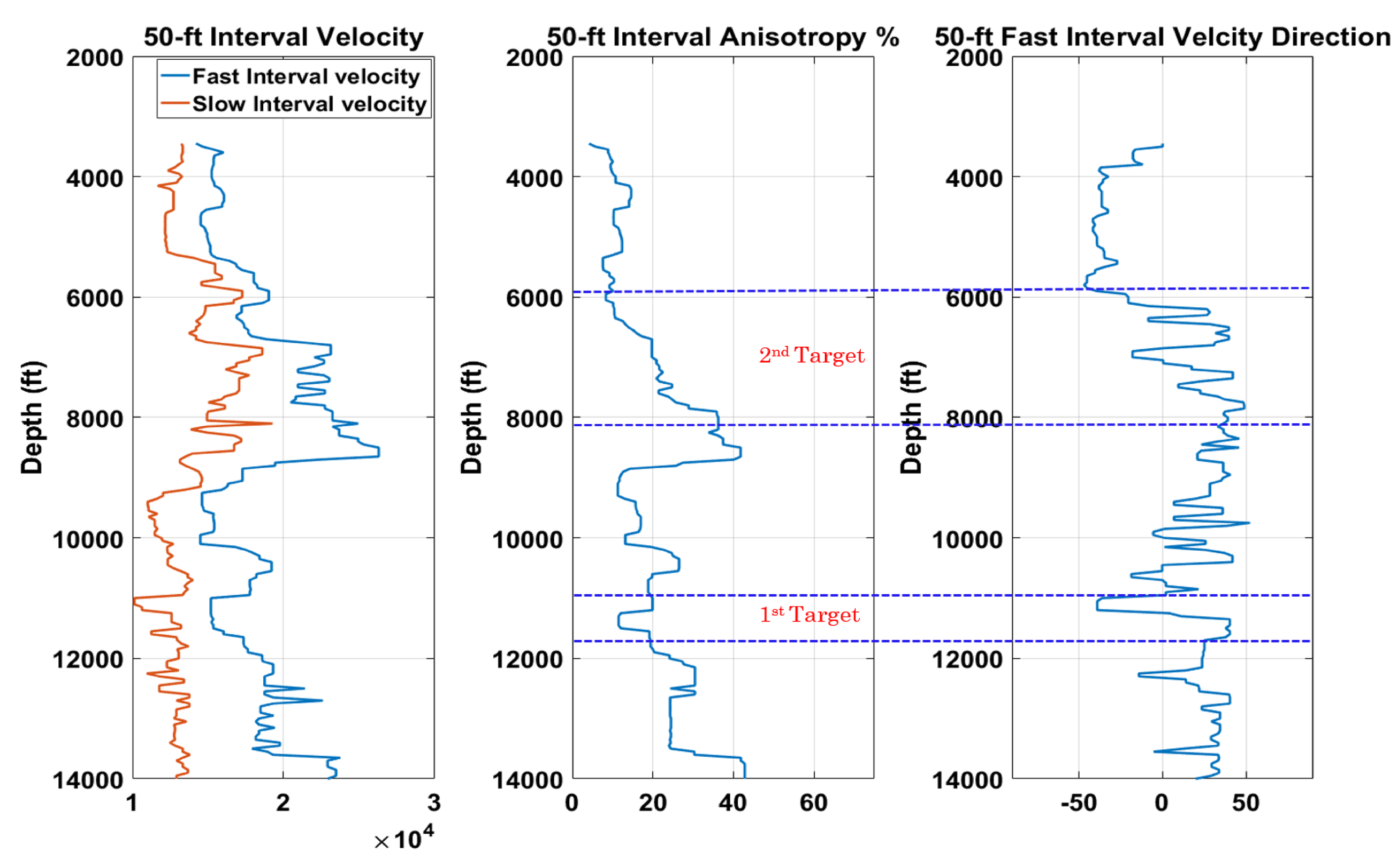


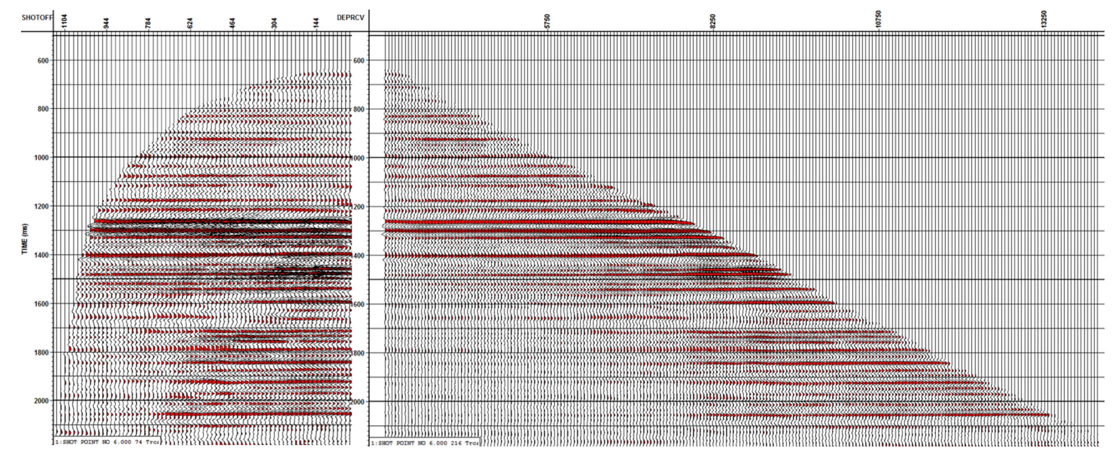
Reflectivity vs offset (top), and reflectivity vs angle of incidence (bottom).



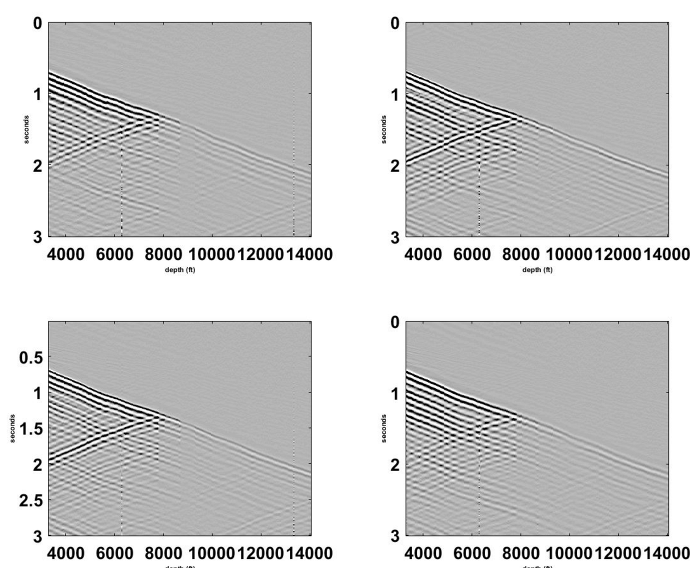
A schematic diagram showing borehole and downgoing raypath from shot to geophone, indicated by black arrow. X is the borehole-shot offset. Vertical raypath from shot elevation is indicated by red arrow. Blue arrow indicates vertical raypath to SRD. The shot to geophone traveltime is calculated from SDR and indicated by green arrow.

50'-interval anisotropy: slow and fast RMS velocity (left), anisotropy intensity (middle), and anisotropy direction (right).

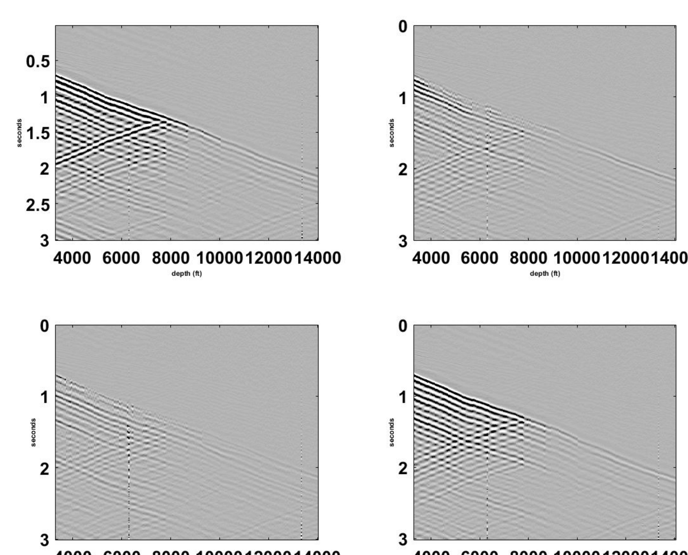




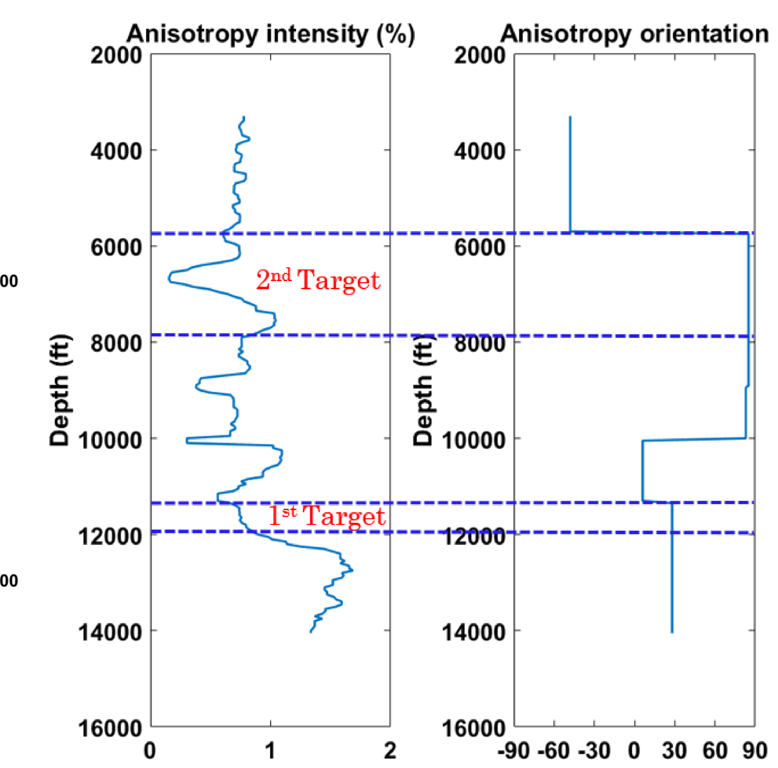
VSP-CDP transform (left) and NMO-corrected upgoing P wave.



4-C VSP before rotation: N-S shot components (top), E-W shot components (bottom), N-S receiver components (left), and E-W receiver components (right).



VSP after rotation and layer stripping: N-S shot components (top), E-W shot components (bottom), N-S receiver components (left), and E-W receiver components (bottom).



S-wave analysis: anisotropy intensity (left) and direction (right).

Summary

For the development of unconventional reservoirs, azimuthal variations of P-wave velocities can be a valuable tool for fracture information. In this paper, we have developed a VVAZ workflow for offset, workaround, or walkaway VSPs using a method for surface seismic. Vertical arrival times for all shots were not very similar at the beginning. Irregular topography and near surface effects were not corrected properly, which would affect the VVAZ method shown here, based on RMS velocity. Therefore, interval anisotropy properties were calculated, as well, to avoid the effects of overburden. The intervals used to calculate the ellipse coefficients involved every receiver (or 50').

The three reservoirs were found to have anisotropy oriented along a NE-SW trend, while the overburden anisotropy was oriented NW-SE. The anisotropy intensity was found to be highest in the Wasatch formation and the lower part of the Upper Green River formation.