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Azimuthal Velocity Analysis of 3D Seismic for Fractures: Altoment-Bluebell Field

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Summary

The 3D seismic data was acquired within Bluebell Field, the eastern portion of Altamont-Bluebell field in northeastern Utah. Altamont-Bluebell field is within the Uinta Basin, and is considered an unconventional reservoir in the sense that natural fractures act as fluid storage and conduits in the tight sandstones and carbonates. Information related to fracture orientation and intensity is vital for the development of such reservoirs. Azimuthal variations of P-wave velocities can be a valuable tool for fracture information. Therefore, this paper utilizes Velocity Variations with Azimuth (VVAZ) to estimate the direction and intensity of fractured-induced anisotropy within one of the reservoirs, Upper Green River formation.

VVAZ inversion method is applied based on the elliptical NMO equation for TI media that was derived by Grechka and Tsvankin (1998). Our code has been tested on a 3D physical modeling dataset and results are shown in another report, Al Dulaijan et. al. (2015). Isotropic NMO velocities are used along with azimuthally variant time residuals to estimate fast and slow NMO velocities and their direction. Hampson-Russell suits VVAZ has also been implemented and results are compared in the report.

Introduction

Bluebell-Altamont field is located in northeastern Utah in the Uinta basin. The Uinta basin is an asymmetric east-west trending basin with a south flank that hat slopes gently. The north flank bounded by east-west trending Uinta Mountains. The Bluebell-Altamont field is located in the northern-central part of the basin. Production is from Tertiary sandstones, shale and carbonates. There are three main targets in the filed: Upper Green River, Lower Green River, and Wasatch (Lynn et. al, 1995).

Bluebell-Altamont field is unconventional in the sense that natural fractures act as storage and conduits in the tight sandstones and carbonates. Bluebell field is the eastern portion of the Bluebell-Altamont field. Its accumulative production is 336 MMBO, 588 BCFG, and 701 MMBW. The objective of this study is to identify density and direction of fractures to help in determining well spacing to existing wells needed to effectively drain remaining hydrocarbon reserves in the Bluebell field, and to identify new drilling opportunities (Adams et. al, 2014).

Seismic data acquisition and processing

3D seismic is acquired over an area of 35 square miles within Bluebell field in 2010. Figure 1 shows a basemap of 3D seismic data, with color indicating fold. Two vibrators were used for each shot and an array of six geophones over a 6' circle were used for each channel. The receiver and source intervals are 220'. The receiver lines are oriented E-W and spaced 1100', while source lines are oriented N-S and spaced 660'. Bin size is 110'x110', and the nominal fold is 240. In addition, a zero-offset VSP survey location is indicated by a black circle.

Refraction statics were applied. Heavy noise were observed and suppressed in multiple domains (i.e., shot, CDP, inline-azimuth-shot line). Also, spherical divergence correction, surface-consistent amplitude corrections, and deconvolution were applied. The zero-offset VSP is used to calculate Q that later was accounted for in the 3D seismic data. Isotropic velocity analysis at one-mile interval and NMO corrections were followed by residual statics. Second pass of velocity analysis at half-mile interval were followed by another pass of residual statics. After muting, data is stacked.

Prior to PSTM, data were binned into Common Offset Vector (COV). COV allows azimuthal information to be preserved after PSTM. Isotropic migration is preformed and followed by VTI analysis, and VTI PSTM. PSTM inline stacks intersecting the VSP are shown in Figure 2 with the reference to the base map (bottom right).

Seismic data analysis

Top of Upper Green River formation and Mahogany bench are picked and indicated by blue and green respectively on the stacked sections in Figure 3. Upper Green River consists of lacustrine carbonate and clay, while Mahogany bench consists of shale and is a very strong marker (Lucas and Drexler, 1976). Mahogany bench is within the Upper Green River formation. The fracture analysis carried in this paper is on the interval from Upper Green River top to Mahogany bench.

Unlike Amplitude Variations with Azimuth AVAz methods, VVAZ methods use base of the target rather than top of the target. The base of the target, the top of Mahogany bench, traveltimes are displayed along the post-stack seismic volume in Figure 5. The Mahogany bench travettimes are shallowest in the northeastern and southwestern part of the survey. At the three main targets, largest incident angles, that can be analyzed, are between 30^{o} to 40^{o}, as shown by Figure 4.

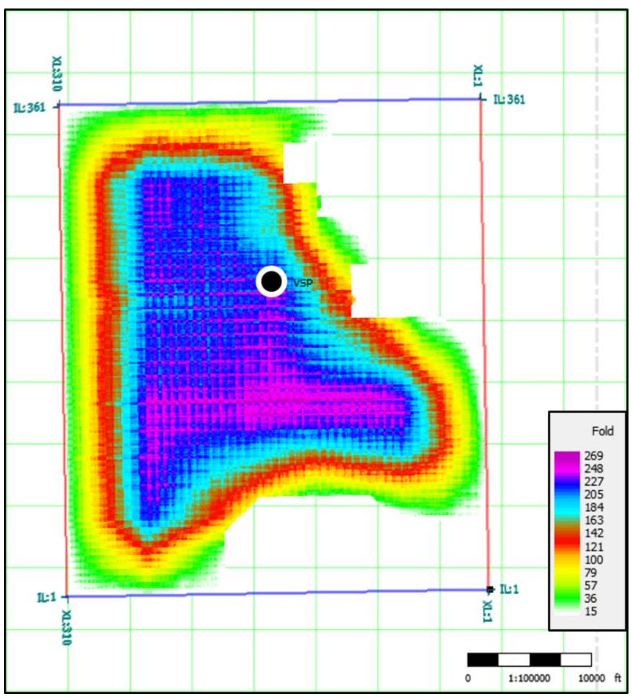

Fig. 1 A basemap of 3D seismic data. Color indicates fold of 110'x110' bins. VSP location is indicated by black circle.

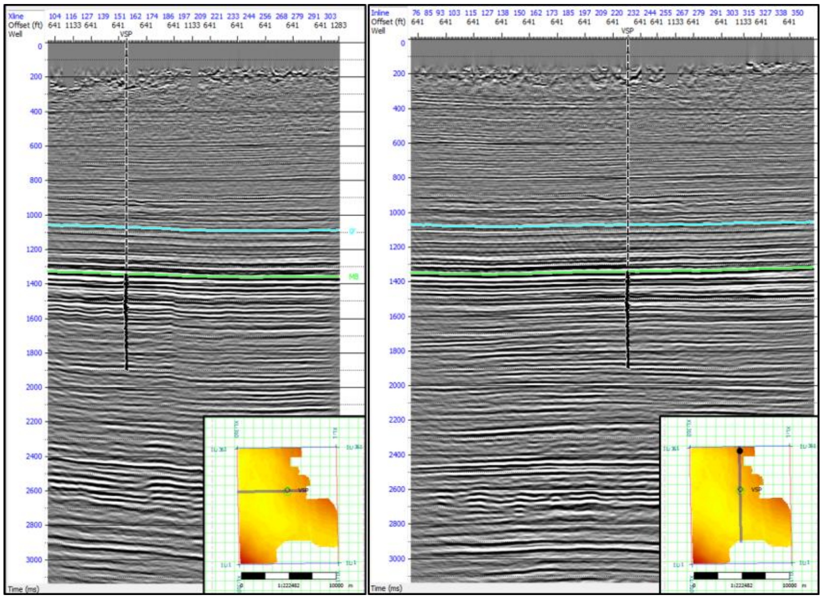

Fig 3. CDP Stack: inline (left) and crossline (right). VSP borehole is indicated in the middle and basemap in the bottom right. Two horizons are indicated Upper Green River (blue) and Mahogany bench (green)

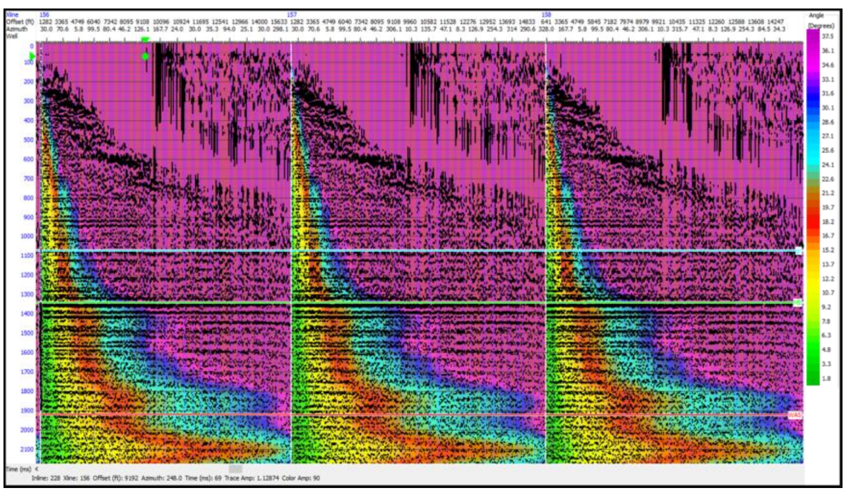

Fig. 4. PSTM image Gather (COV). Color indicates angle of incidences. At target levels, maximum angles are 30^o to 40^o.

Results

VVAZ inversion has been performed in Matlab as described above to the part of the Mahogany Bench around the VSP. Fast RMS velocity, slow RMS velocity, and their directions were calculated. Figure 5 compares isotropic RMS velocity to fast and slow RMS velocities. Coordinates are with reference to the VSP borehole. From those three velocities, a velocity anisotropy percentage was calculated by dividing the difference between the fast and slow RMS velocities by the isotropic RMS velocity. Besides the method described above, VVAZ was performed in Hampson-Russell Suites, and the results are compared. Figures 6 and 7 compare the percentage and direction of anisotropy obtained by our code to Hampson-Russell's. We can see that anisotropy percentage obtained by both methods go up to less than 1.5%. Higher anisotropy zones, in both maps, are observed in northeast and southwest. In Figure 7, it can be seen that anisotropy orientation, obtained by methods, falls in the same quadrant. Arrows on left map from top to bottom have values of 40^o, 19^o, and 43^o from *x*-axis.

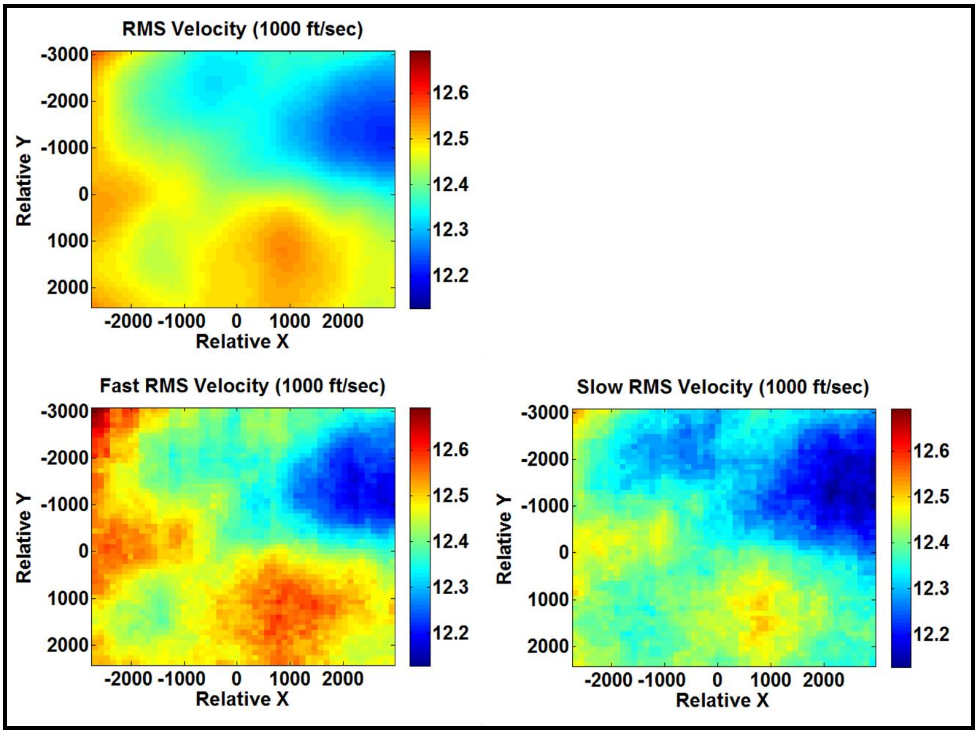

Fig. 5. Isotropic RMS velocity vs. fast RMS velocity vs. slow RMS velocity in (1000 ft/s).

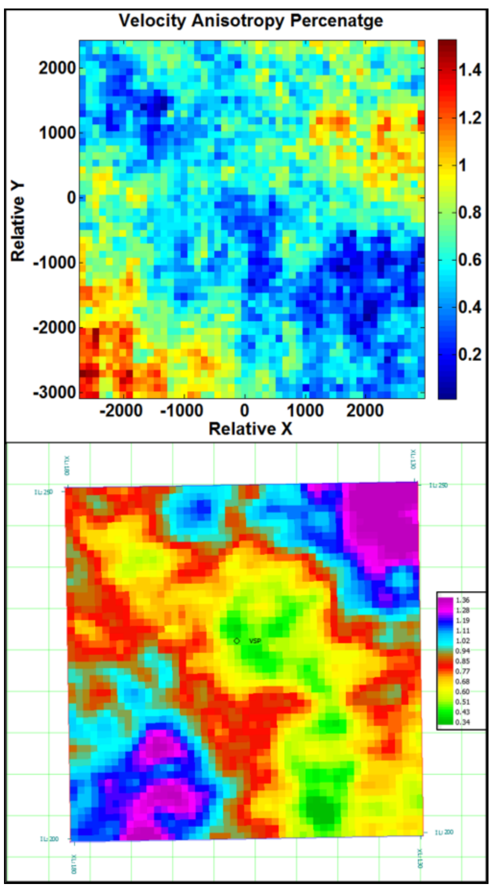

Fig 6. Comparison of anisotropy percentage obtained by two methods.

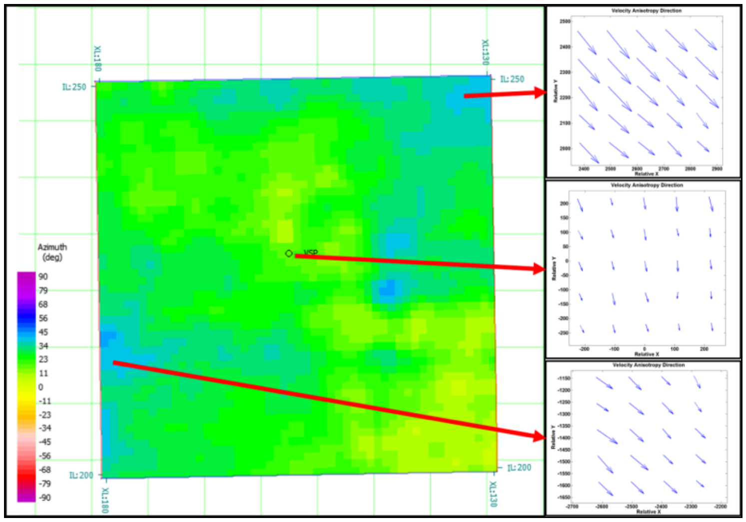

Fig 7. Comparison of two methods of VVAZ. Color on left map indicates angle of fast velocity from the x-axis. Arrows on left map from top to bottom have values of 40^o, 19^o, and 43^o from *x*-axis.

Conclusions

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 implemented an AVAz workflow to 3D pre-stack seismic data from Altamont-Bluebell field. Our target was the shallowest from the three targets of Uinta Basin, Upper Green River to Mahogany Bench. Maps of anisotropy intensity and direction were obtained and compared to maps that we obtained using Hampson-Russell Suites. Both direction and intensity maps correlate well in both models.

Acknowledgments

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