VSP azimuthal travel time analysis at the Field Research Station near Brooks, AB.

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Summary

As part of the Containment and Monitoring Institute (CaMI) CO_2 injection project, 3C Vertical Seismic Profile data (VSP) were acquired at the Field Research Station in May 2015. A half walk-around VSP survey was acquired and processed for an azimuthal analysis. Obtaining the first break traveltime variations with azimuth, was the first step. Statics corrections and median filters were applied to help differentiate a sinusoidal trend in the data. The fast velocity direction, estimated from the trend, is at an azimuth of approximately 50 degrees, which is similar to the Western Canada stress orientation (NE-SW). An estimation of the anisotropy parameter epsilon (ε) yield a value of 0.02, indicative of weak anisotropy.

Introduction

The Containment and Monitoring Institute (CaMI) is developing a Field Research Station (FRS) in junction with the University of Calgary. The objective of FRS is to facilitate and to accelerate research and development leading to improved understandings and technologies for geological containment and storage of CO_2, monitoring of fossil fuel production, and environmental mitigation (Lawton et. al., 2014).

The purpose of this project is to identify azimuthal anisotropy at the Field Research Station (FRS) in order to characterize the study area where the CO_2 injection will take place. Therefore, the velocity changes will be analyzed by processing a half walk-around vertical seismic profile (VSP) data acquired on May 2015.

Data set and procedure

In May of 2015 a 3C walk-away and half walk-around Vertical Seismic Profile (VSP) survey was recorded at the FRS with the collaboration of the Microseismic Industry Consortium. The area of study is located in southern Alberta, approximately 189 km southeast of Calgary and 25 km southwest of Brooks (Figure 1a). The acquisition design for the VSP surveys as illustrated in Figure 1b; centered on the well 10-22. A three-component ESG SuperCable was deployed in the well at three different levels, giving receiver positions in the well ranging from 106 to 496 meters depth with 15 m spacing. The source was an IVI EnviroVibe, sweeping from 10-200 Hz linearly over 16 seconds with an additional 4 seconds listening time. Two source lines were acquired three times, once for each tool position in the well. Source line 208 (NE-SW) had 10 m Vibe Points (VP), offset NW of the surface receiver locations, for a walkaway VSP. A semi-circular source line (204) with a radius of 400 m and a VP every five degrees was acquired for a velocity tomography study and an azimuthal analysis (Hall et. al., 2015).

Results

In order to undertake azimuth velocity analysis, the first break traveltimes of the walk-around VSP were plotted for each receiver as a function of azimuth. By sorting seismic data into azimuthal gathers, a sinusoidal variation in traveltime with azimuth would generally indicate the presence of azimuthal anisotropy (HTI) (Liu et. al., 2012). Due to the regional stress field of the study area, the possibility of fractures is not unlikely. Since the acquisition configuration for the walk-around is a semi-circle, we would expect a sinusoidal traveltime variation. One remark about this graph (Figure 2) is the high precision of the first break picks for all the receivers, almost each point is in resonance with the general trend. However, the graph has a considerable amount of noise and therefore a statics correction was applied.

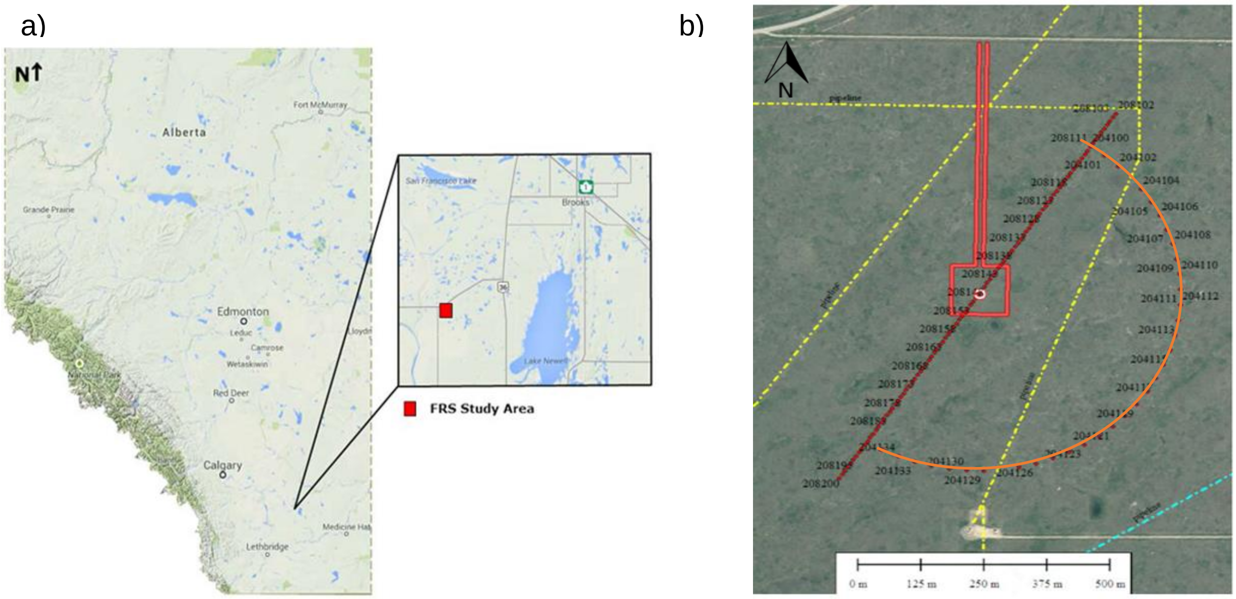

Figure 1. Study area location (a) and VSP survey geometry (b).

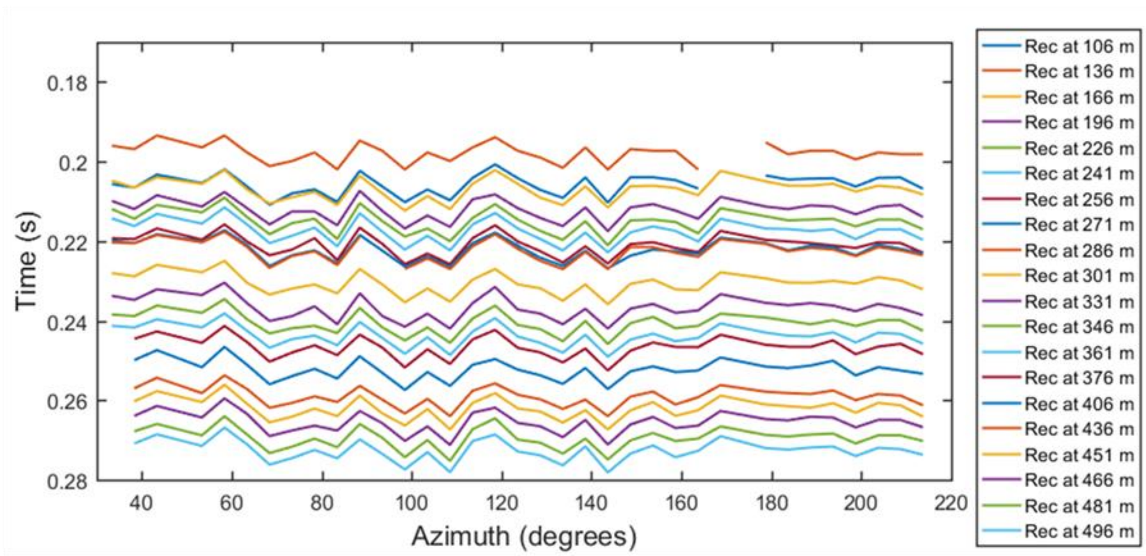

Figure 2. Traveltime variation per receiver as a function of azimuth.

The shot statics from the 3D seismic survey in the study area were used to apply the static corrections to the observed traveltimes. The variations may be associated with the near-surface layer and not to topography, since the FRS is located in a generally flat area. With the use of MATLAB, all the shot statics around the study area were interpolated and plotted to create a contour map of the shot statics. The shots of the VSP survey were superimposed over the contour map. The static values for each shot were imported to VISTA and once the correction was made, the plot of the first break traveltimes versus azimuth was edited. Since the values of the shot statics were considerable small, noise is still present. However, some small variations are visible after correction, as on the edges of the chart where the curves have a flatter and steadier appearance. Several median filters were applied to the data in order to smooth the trend present in the plots. Figure 3 shows the graph obtained after a median filter of 7 samples was applied. With this filter the noise trend is attenuated and a flatter shape is observed. By reviewing the data at a larger scale (Figure 4) it is possible to distinguish a sinusoidal trend more clearly.

From this result, we could state that the fast direction is around a 40-90 degrees azimuth which has a similarity with the stress orientation in Western Canada (NE-SW).

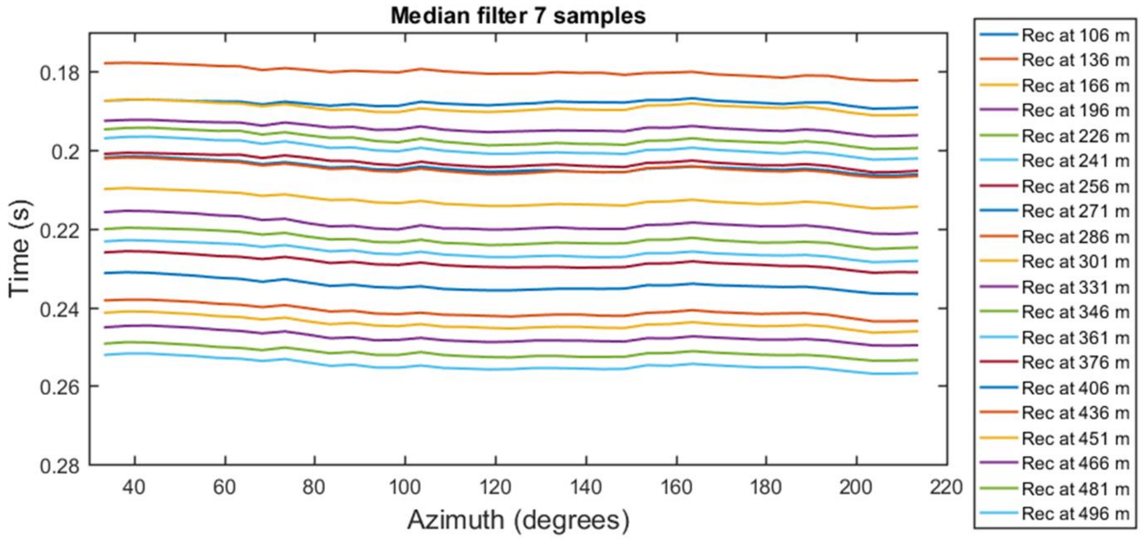

Figure 3. Traveltime variation after statics correction and smoothing function.

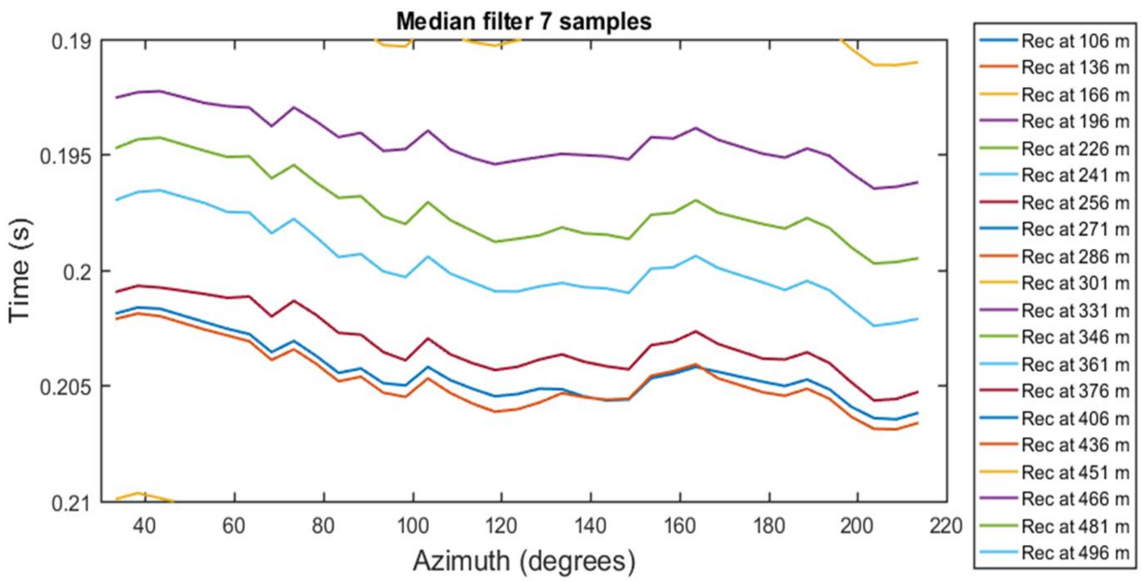

Figure 4. Traveltime variation at a larger scale.

The following step was a residual estimation by fitting different polynomial equations of different orders to the data in a least-squares sense. This estimation was done for the 1st and 3rd order polynomials at three receiver locations (shallow, middle and deep). Figures 5 and 6 represents the residual calculation in time and velocity variation of a shallow receiver, showing, in the first plot the fitting lines overlain on the data, and the residuals obtained from each fitting line in the second plot. As we can see, the 3rd order approaches better to the data, and the residual values range from -2 to 2 milliseconds and -20 to 20 m/s, respectively. From the velocity variations, we were able to estimate the anisotropy parameter epsilon. This calculation was done for the same three receivers locations. The average result obtained was 0.02. This small value of epsilon is indicative of weak anisotropy. For future work, the residual estimation could be associated to a mathematical equation with the attempt to estimate anisotropy parameters.

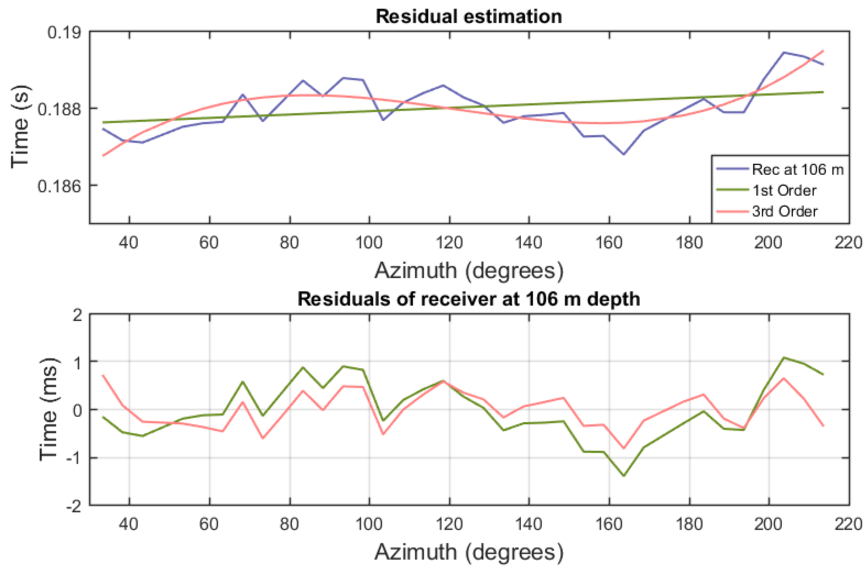

Figure 5. Traveltime residual estimation of shallow receiver at 106 m depth.

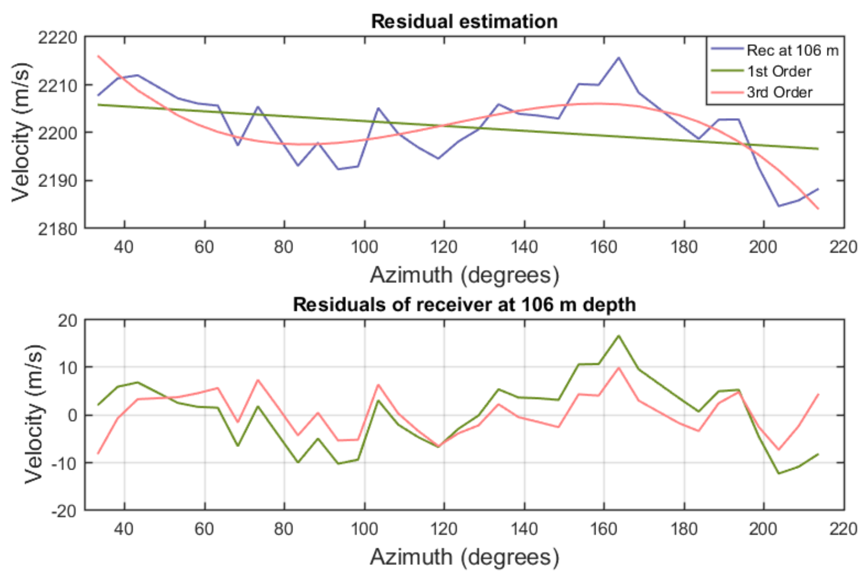

Figure 6. Velocity residual estimation of shallow receiver at 106 m depth.

Conclusions

The VSP azimuthal analysis was performed by studying the velocity changes in the first arrivals. This was done with the first break traveltime variation in respect to the azimuth of every receiver, and it showed good precision in all the points of the plot. After the static corrections and a median filter were applied, a smoother trend was observed. A sinusoidal trend is noticeable for the traveltime variation, which is indicative of azimuthal anisotropy (HTI). The fast direction shown is to the NE. With the traveltime and velocity residual calculation we were able to estimate an approximate value for epsilon equal to 0.02, indicative of weak anisotropy.

Acknowledgements

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