Analysis of time-lapse, multicomponent seismic data from a potash mining area in Saskatchewan

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ABSTRACT

Seismic anisotropy is a subsurface property that can have a severe impact on the quality of subsurface seismic imaging. In this study, a multicomponent, time-lapse seismic survey is interpreted to determine if seismic anisotropy exists in a potash mining area in Saskatchewan. The focus of this study is the Devonian Dawson Bay Formation which is made up of fractured carbonates and thus may allow fluid to propagate downward from an aquifer into the underlying Prairie Evaporite Formation. The seismic volumes were split into 4 azimuthally sectored sub-volumes that are made up of a stack of source-receiver ray paths covering a 45 degree sweep. Through interpretation and travel-time analysis of these data, it has been found that carbonates of the Dawson Bay exhibit azimuthal velocity anisotropy, possibly due to fractures, although it is not possible to determine the cause of the anisotropy with this analysis.

ANISOTROPY

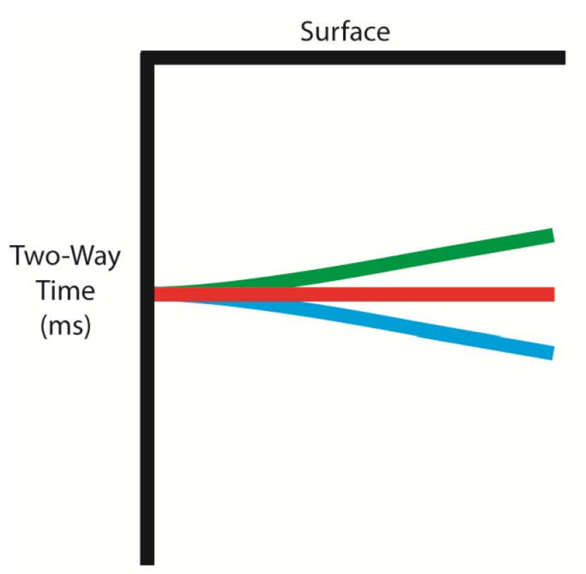

FIG. 1. A cartoon showing the difference between the full azimuth, fast velocity azimuth and slow velocity azimuth shot gathers. The red lines represent the full azimuthal gathers where the green and blue lines represent the fast and slow velocity events respectively. Vertical fractures induce horizontal transverse isotropy (HTI) in the subsurface due to the lack of cohesion across fractures. This results in a reduction in seismic velocity and an increase in travel time perpendicular to the fracture orientation.

DATASET

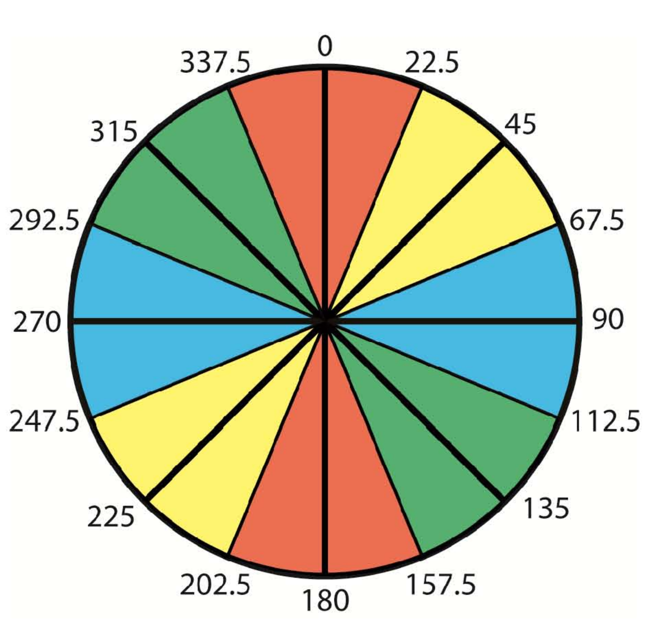

FIG. 2. Pie chart showing the distribution of ray paths which make up each of the azimuthally sectored seismic volumes. The full azimuth volume is made up of a stack of all azimuths.

HORIZON INTERPRETATION

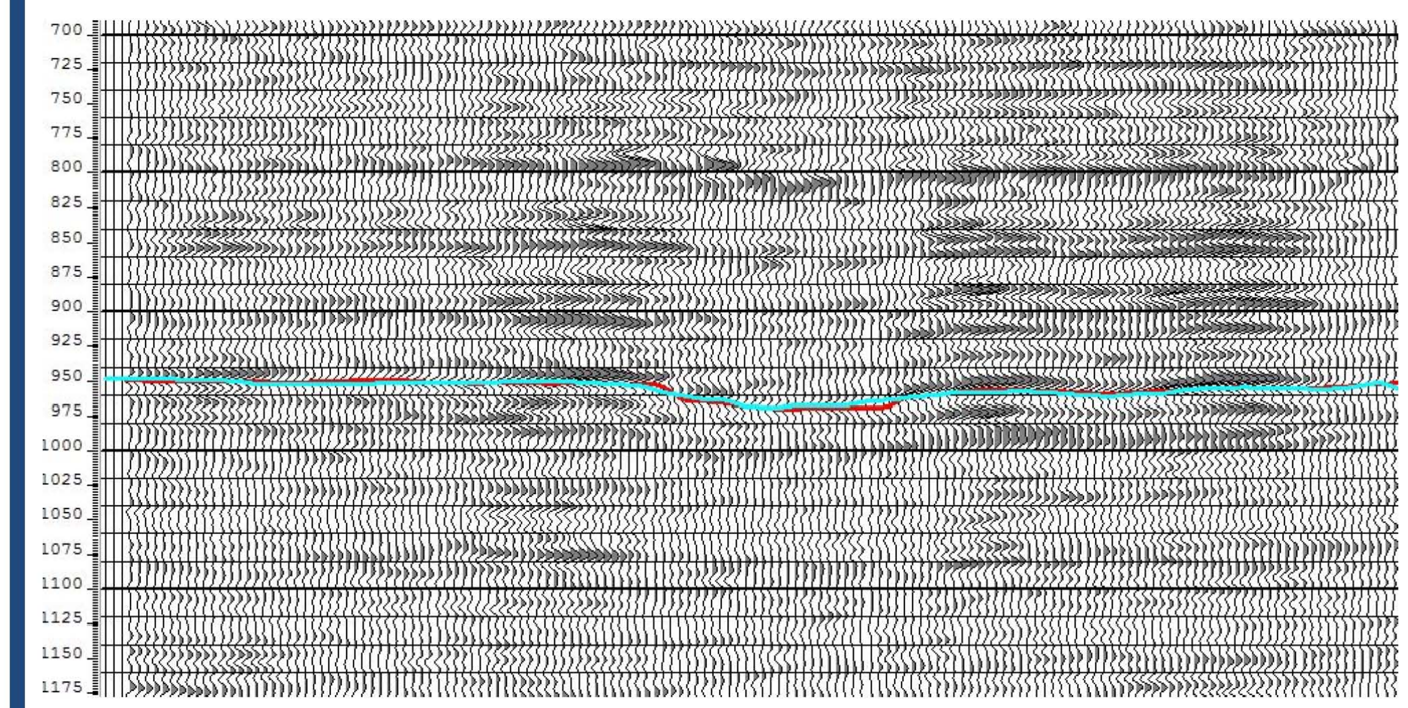

FIG. 3. Here, inline 105 shows the Winnipegosis horizons picked for the 2004 45&225 (blue) and 135&315 (red) azimuthally sectored seismic volumes. The differences in travel times between these two horizons is the result of anisotropy in the stratigraphy above these reflectors and could be, in part, due to fractures.

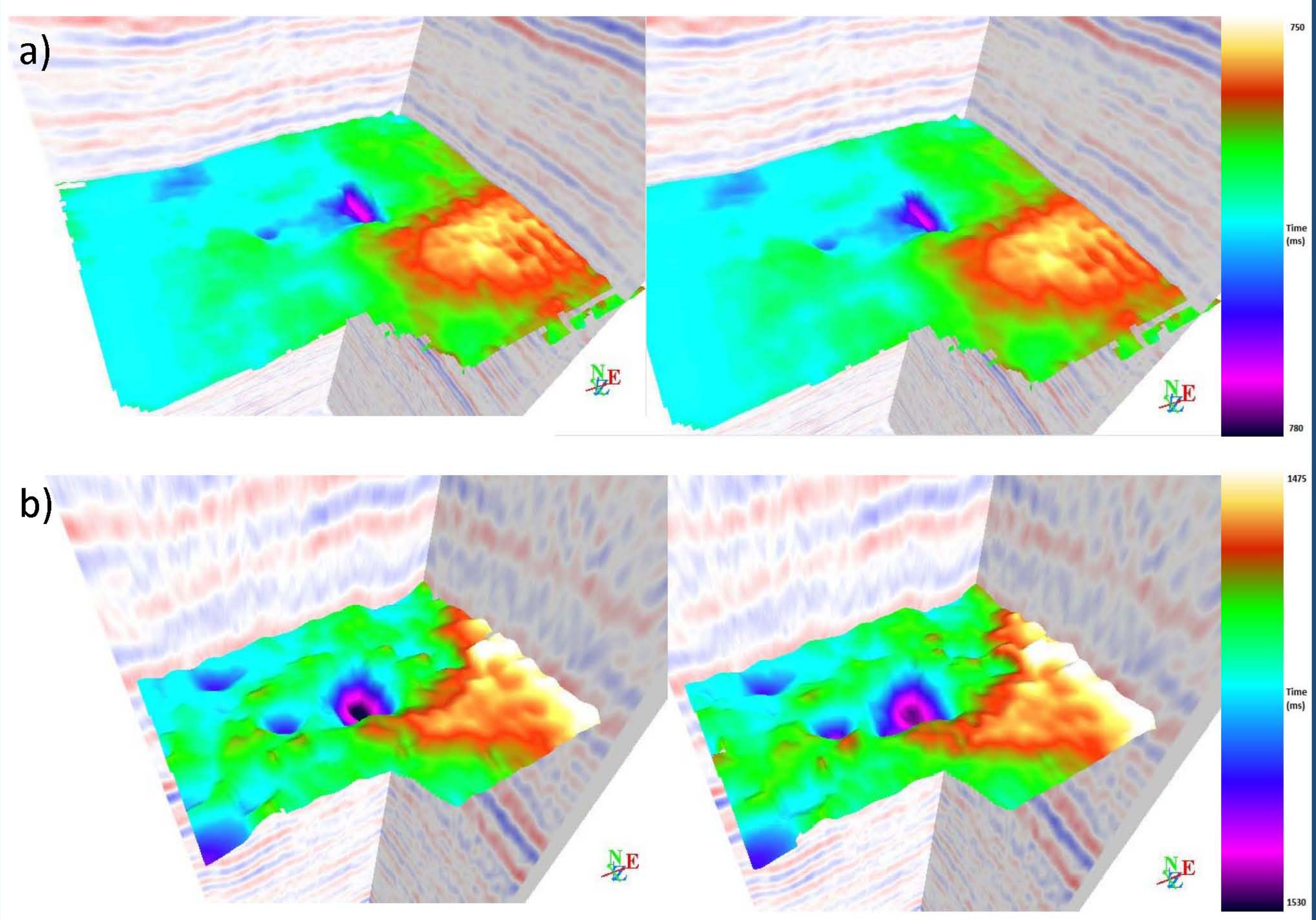

FIG. 4. a) The 2004 (left) and 2008 (right) Dawson Bay horizons picked from the compression wave, full azimuth seismic volume.
b) The 2004 (left) and 2008 (right) Dawson Bay horizons picked from the converted wave, full azimuth volumes.

ANISOTROPY INTERPRETATION

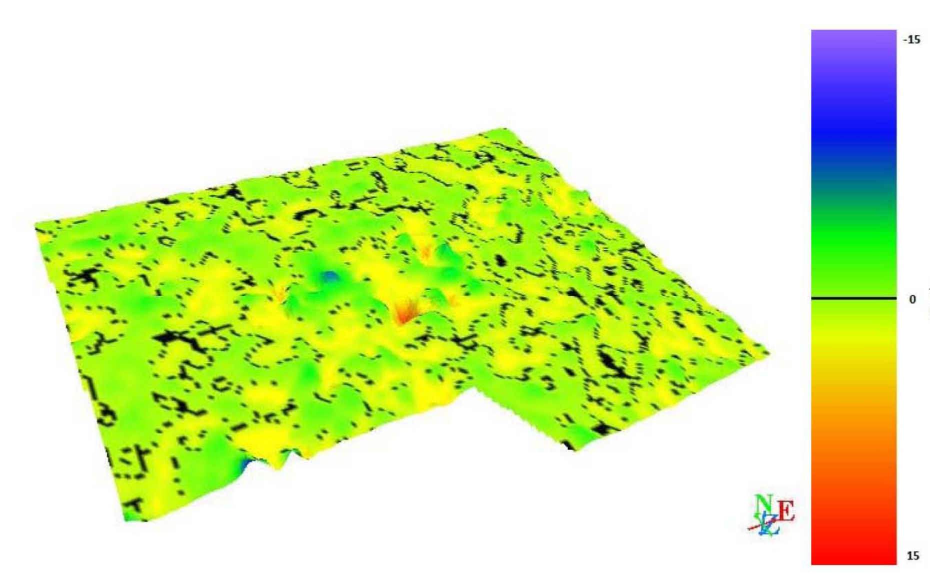

FIG. 5. The 2004 two-way travel time difference plot for the Winnipegosis Formation shown in 3D. The blue represents a negative travel time difference and the red represents a positive travel time difference between the horizon picked from the 45&225 degree sectored volume and the horizon picked from the135&315 degree seismic volume.

ANISOTROPY COMPARISON

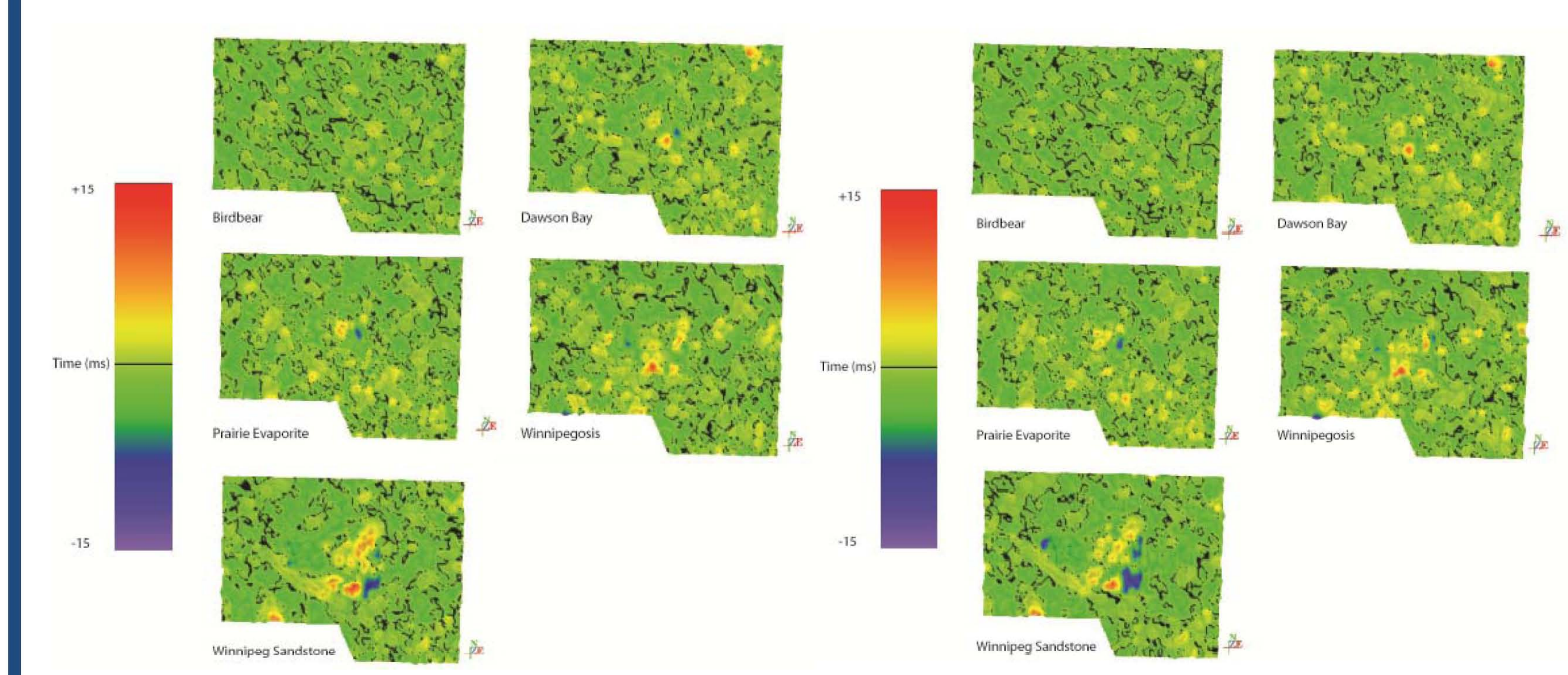

FIG. 6. 2004 (on left) and 2008 (on right), 45&225 – 135&315 difference plots with positive and negative travel time differences indicating a preferential fracture orientation in the 135&315 and 45&225 directions respectively.

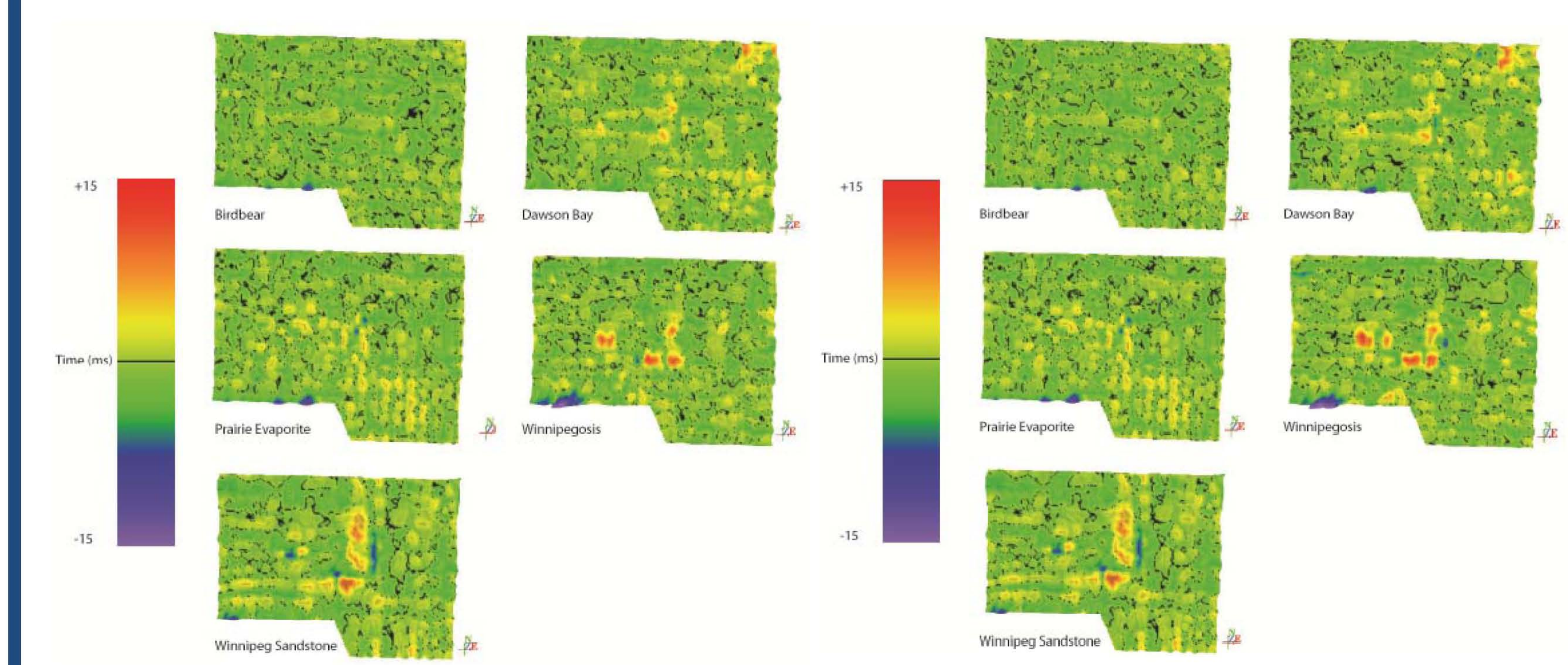

FIG. 7. 2004(on left) and 2008 (on right), 0&180 – 90&270 difference plots with positive and negative travel time differences indicating a preferential fracture orientation in the 90&270 and 0&180 directions respectively. Some acquisition footprint residual is also visible in the difference plots.

CONCLUSION

Examination of these results show a dominant reduction in seismic velocity in the 0&180 degree orientation in both the 2004 and 2008 surveys. These findings support a fractured Dawson Bay Formation, though it is unclear as to whether or not the anisotropy is developed within the Dawson Bay or the strata below. In order to determine the cause of these anomalous two-way travel time differences, further analysis of the multicomponent data acquired, as well as seismic attribute analysis is needed to constrain the subsurface lithology, and the extent of the discontinuities present that may be influencing the fracture networks.

ACKNOWLEDGEMENTS

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