3D Curvature Analysis for Investigating Natural Fractures in the Horn River Basin, Northeast British Columbia

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Summary

A 3D multicomponent seismic dataset from the Horn River Basin was assessed for mapping fractures. The data had good fold, offset and azimuth distributions and several approaches were used to interpret the distribution of natural fractures. In addition to amplitude mapping, PP and PS curvature maps enhanced the structural interpretation of the data and enabled the lateral continuity of faults and fractures to be mapped across the area of the seismic survey.

Both horizon and volume based most negative curvature were effective in mapping fault and fracture trends within both Exshaw and Muskwa shale gas targets. At the Exshaw level, the curvature shows two main fault trends: northwest-southeast trending normal faults that dip toward the southwest, as well as northeast-southwest strike-slip faults. At the Muskwa level, the curvature image shows different major fault trends, namely north-south, northeast-southwest, and northwest-southeast faults (normal and reverse faults). Fractures interpreted using curvature attributes are close to the major faults and their dominant trends are generally parallel to the major faults in the area.

Curvature analysis

Recently, the curvature attribute have been used to recognize subsurface geological features such as faults/fractures and channels (Chopra et al., 2006). Mathematically, it is the computation of the second order derivative of the curve (Chopra et al., 2006). In 2-D curve, it is the reciprocal of the radius of a circle that is tangent to the curve at any point on it (Figure 9a) (Chopra et al., 2006). While in 3-D, the curvature analysis can be computed by applying the same curvature in 2D analysis on the intersections of two orthogonal planes with the 3D surface (Chopra and Marfurt, 2007). This computation can be made on two scenarios:

1- Horizon based

2- Volumetric based

Since the volume-based curvature is computed from a time window of seismic data, the result are statistically less sensitive to backscattered noise and has a higher signal-to-noise ratio than horizon-based curvature (Chopra and Marfurt, 2007). Horizon based computations require high quality seismic data and a strong impedance contrast on the horizon of interest, whereas volume-based curvature do not need a picked horizon to do the analysis (Chopra and Marfurt, 2007).

Both analyses were calculated on the 3D data and the results are shown in Figures 1, 2, 3 and 4. Figure 1a shows the horizon-based most negative curvature for the top of the Exshaw horizon which shows the three normal faults, indicated by the blue arrows, the two possible strike-slip faults indicated by the white arrows as well as interpreted acquisition footprint throughout the survey area highlighted by the red ellipses. Figure 1b shows the 0.894 second time slice of the volume-based most negative curvature computed on the PP volume, which shows the three normal faults indicated by blue arrows, as well as the two possible strike-slip faults indicated by white arrows. Figure 2a shows the 1.208 second (Exshaw Formation) volume-based most negative curvature computed on the PS volume, which shows the three normal faults indicated by blue arrows. It also shows two features that are believed to be artifacts generated by a significant channel system within the near surface indicated by white arrows. These subsurface channels are shown in refraction bedrock map (Figure 2b).

Figure 3a shows the computed horizon-based most negative curvature for the base of Muskwa horizon which shows the two major faults at this level, indicated by the black arrows. The computed volume-based most negative curvature at the level of the base Muskwa shale, represented by the 1.52 second time slice is, shown in figure 3b. It shows clearly different major faults cutting this section indicated by black arrows and circular features which possibly interpretated to be mounds or karsting, indicated by white arrows. These featured is not mapped by the horizon-based attribute Figure 3a.

Fracture detection using seismic amplitude data is a very challenging task due to the limitation in the frequency bandwidth which reduces seismic resolution. Despite the fact that fracture is a sub-seismic geological feature, curvature, particularly the computed volume-based most negative curvature, is interpreted to delineate fracture systems. Their signature appear in this attribute analysis as a relatively medium to high negative curvature value. In this case study, zones of natural fractures are mainly detected close to the major faults (Figure 1b, 3b and 4). The dominant trends of these fractures are generally parallel to the major faults in the area (Figure 4).

Conclusions

Curvature attribute analyses enhance the structural interpretations, such as faults and fractures and map their lateral continuity throughout the seismic volume. Both horizon and volume computed based most negative curvature have been used to map faults and fractures trends at both Exshaw and Muskwa shale gas targets. At the Exshaw level, the curvature shows two main fault trends: northwest-southeast trending normal faults that dip toward the southwest and northeast-southwest strike-slip faults.

At the Muskwa level, the curvature image shows different major fault trends: north-south, northeast-southwest (normal and reverse faults), and northwest-southeast faults. The interpreted fractures using curvature attribute are those fractures that are close to the major faults and their trends are generally parallel to the faults.

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References

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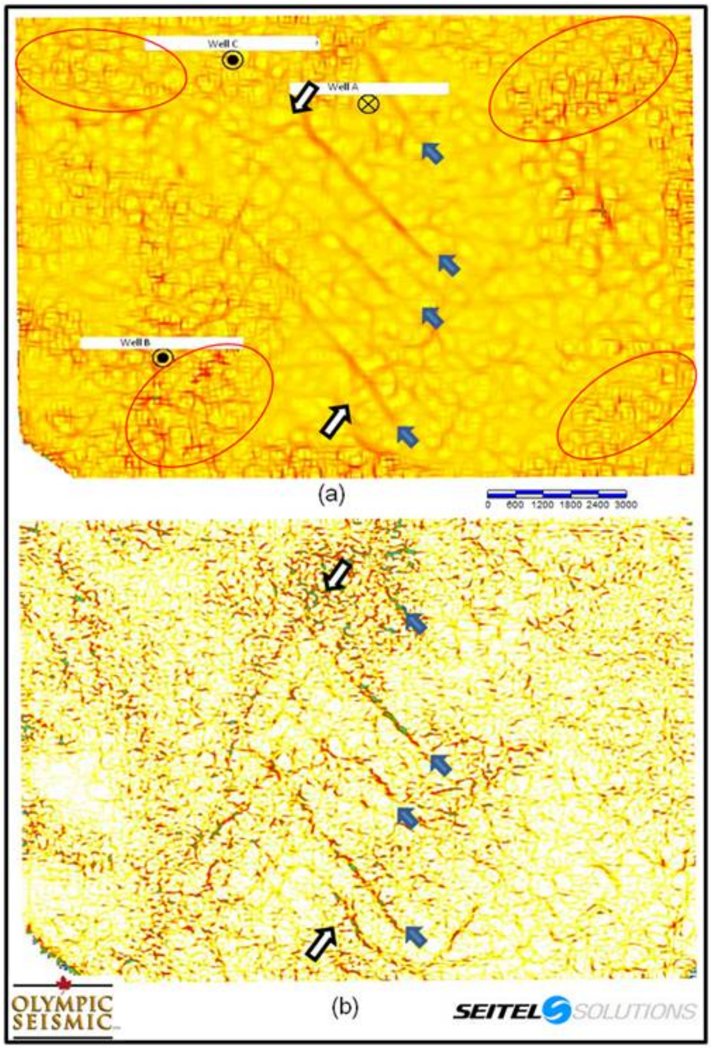

Figure 1: (a) Horizon-based most negative curvature for the top of Exshaw horizon (b) 0.894 second time slice of the volume-based most negative curvature computed on PP volume. Red ellipses indicate acquisition footprint. The blue arrows show the three normal faults and the white arrows show the two possible strike-slip faults.

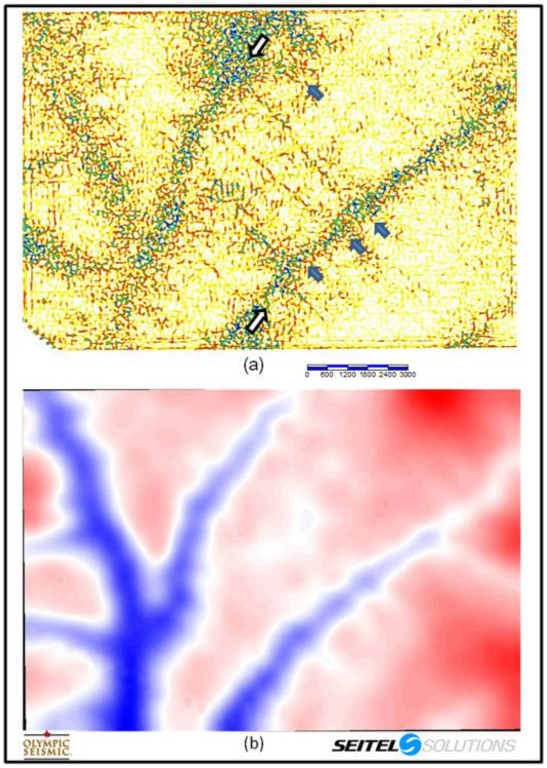

Figure 2: (a) 1.208 second volume-based most negative curvature computed on PS volume (b) base of weathering map.

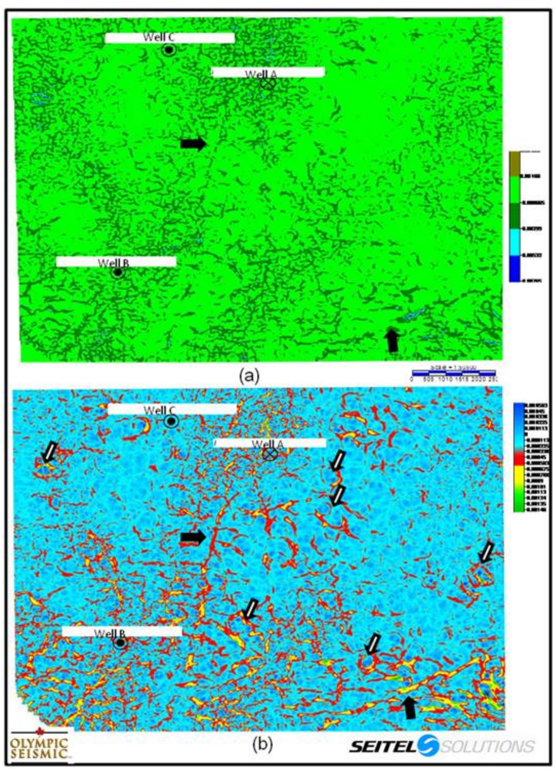

Figure 3: (a) Horizon-based most negative curvature for the base of Muskwa horizon (b) 1.52 second time slice of the volume-based most negative curvature computed on PP volume. The black arrows indicate the two major faults and the white arrows show circular features which possibly interpreted to be mounds or karsting.

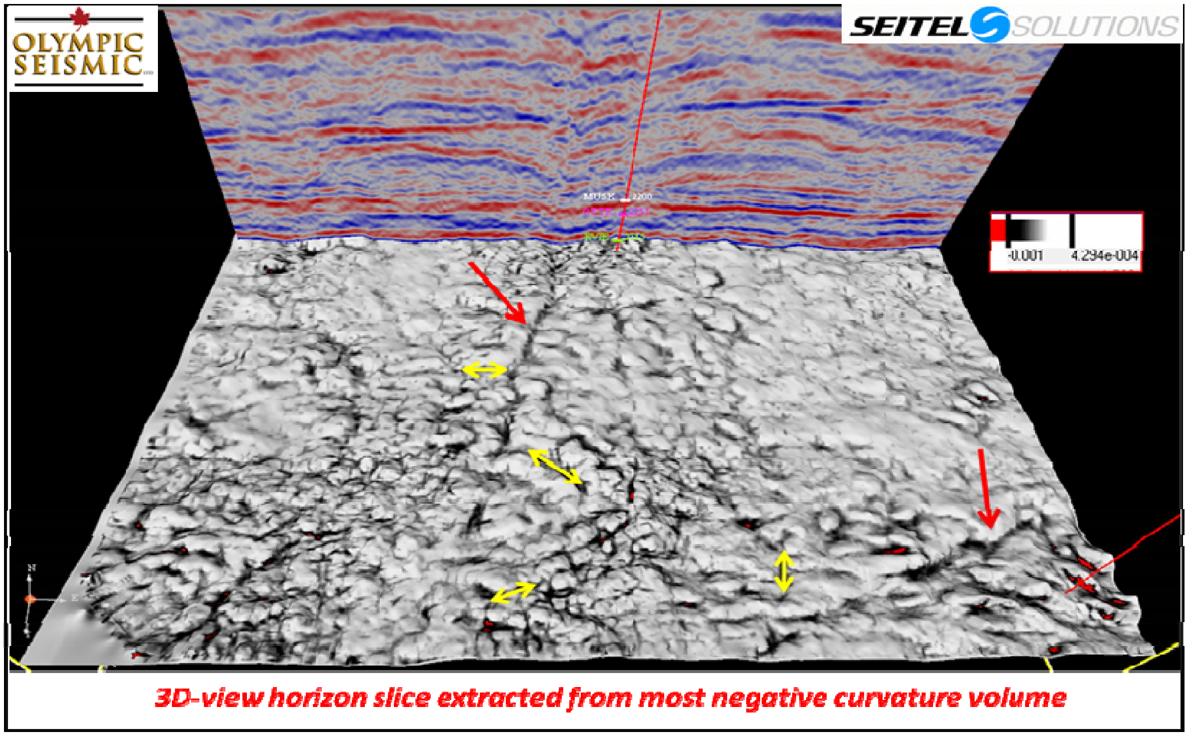

Figure 4: Horizon-slice through the most negative curvature volume at the base of the Muskwa horizon shows the two major faults indicated by the red arrows and the four fracture trends in the area highlighted by the yellow arrows.