Diffraction Imaging Case Study – Slipping Through The Cracks

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Summary

Volumetric attributes, such as Coherence and Curvature, have been the standard tools for the interpreting geophysicist when it comes to direct discontinuity detection. We examine the methadology of Pre-stack Migration Diffraction Imaging (DI) and provide three depositional Western Canadian Sedimentiary Basin case studies to compare the three techniques.

Introduction

Although hydraulic stimulation techniques have been around for 60+ years, it has only been in the last decade that a shale production revolution has taken hold of North American energy development. The recent rise in the development of large gas and oil rich shale basins through stimulation has led to unparalleled growth in North American unconventional hydrocarbon production. In the United States1995 shale gas provided 1.5% of total gas production, 2005 provided 4.2%, 2010 provided 22.8%, and it is estimated that by 2020 41.5% of gas production will be from shale gas basins (US Energy Information Administration, 2012). As the industry embraces production successes, un-mapped and un-resolved faults have created issues such as loss of circulation pressure and loss of hydraulic fluid volumes. Mapping of up-hole fault systems is gaining importance.

Theory/Method

Although the concept of using diffracted or scattered waves has conceptually been around for a while (Krey,1952; Hagedoorn, 1954; Landa et al., 1987) only recently has the application of pre-stack Diffraction Imaging been practical and achievable.

Reflective seismic data processing has conventionally focused on the resolution of specular reflections through the estimation of subsurface velocities to reconstruct the geometries of continuous reflection interfaces (Khaidukov et al, 2004). Specular reflection describes backscattering if the seismic wavelength is small compared to characteristic length scale of discontinuity, whereas diffraction is the seismic response from a strong curved interface, edge or tip (Moser, 2011). One limiting factor for vertical resolution of conventional reflective seismic processing is the Rayleigh limit, where the bed thickness needs to be ¼ of the dominant wavelength to be resolved (Born and Wolf, 1959; Sheriff, 1997; Chen and Schuster, 1999). Khaidukov (2004) discusses the concept of superresolution achieved through Diffraction Imaging which is defined as the recovery of smaller details beyond the seismic wavelength, or subwavelength scale details.

Faults, cracked interfaces, stratigraphic pinch-outs, and channel edges are all diffraction generating geological interfaces that are encoded within the full seismic wavefield. Often these events are masked, unresolved, unfocused, or highly laterally interpretable. The objective of diffraction imaging is to isolate the diffractive wavefield by suppressing the specular wavefield and re-migrating the isolated diffraction energy. The benefits are to improve image resolution, resolve faults, illuminate edges, and improve the interpretability of otherwise masked or non-reflective events.

Case Studies:

The objective is to compare and assess the benefits and drawbacks of volumetric attributes of Coherence and Curvature with those of the pre-stack Diffraction Imaging volumes. The example data set below is taken from the Western Canadian Sedimentary Basin.

Figure 1 shows a Pre-Stack Depth Migration Amplitude horizon slice. Channels are broadly defined and potential faults are interpretable but masked and un-focused.

Figure 2 shows the corresponding Pre-Stack Depth Migration Coherence horizon slice. Some focusing of edges, significant noise affecting the event continuity.

Figure 3 shows the corresponding Pre-Stack Depth Migration Diffraction Imaging horizon slice. Continuous faults are focused and channel edges are defined.

Conclusions

As a complimentary facet of the complete discontinuity picture (which includes coherency, curvature, AVAZ/VVAZ, PSTM HTI scanning, converted wave processing) Diffraction Imaging is a pre-stack discontinuity determination tool that proves it holds a place in the geophysics attribute toolbox. In areas of low vertical resolution, faults are illuminated and interpretable; channel edges and inter-channel features are distinguishable and can be confidently mapped. Diffraction Imaging has proven valuable in focusing the discontinuities from the WCSB examples.

Acknowledgements

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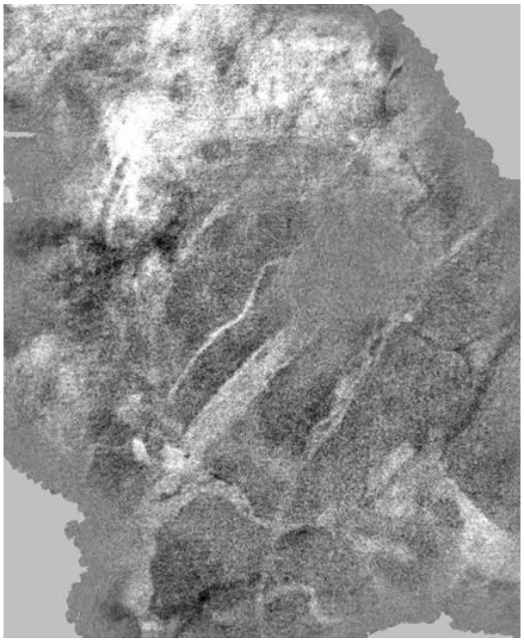

Figure 1. Pre-stack Depth Migration amplitude horizon slice

Figure 2. Pre-stack Depth Migration coherence horizon slice

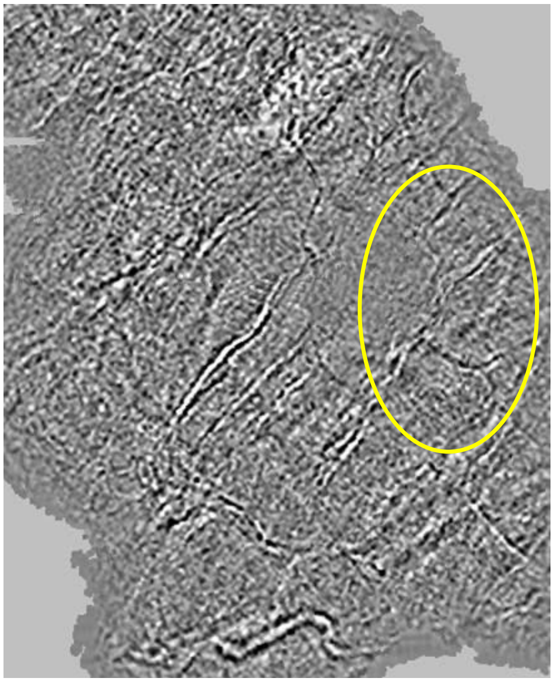

Figure 3. Pre-stack Depth Migration Diffraction Imaging horizon slice