Seismic diffraction imaging of lithology in fault zones and hydrocarbon sweet spots within the Maverick Basin, South Texas

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Abstract

Diffraction events are recorded along with reflection data during seismic acquisition. However, after processing, final migrated stack data are devoid of diffraction events, which have been collapsed to discrete points, smoothed out, and overshadowed by reflection events. Thus, diffraction events that ought to be available for analysis of the rock are lost.

In this presentation, we segregate diffractions, and then build a 3D diffraction volume that not only images faults but also contains amplitude information used to examine lithological composition in fault zones within the Austin Chalk and Eagle Ford Shale in South Texas. The interpretation reveals that zones with moderate to high diffraction energy correspond to zones that are moderately to strongly faulted, whereas zones with little or no diffraction energy correspond to zones with very minor or no faults.

We then transform the diffraction data into amplitude envelope volume. This seismic attribute, together with clay volume ($V_{CLAY}$) data, is extracted along interpreted horizons and fault planes. Cross plots between seismic attributes and $V_{CLAY}$ show that $V_{CLAY}$ increases with increasing diffraction energy. In addition, we observe that the higher the diffraction energies, the higher the fluid saturation, suggesting higher impedance contrast at diffraction points. Furthermore, cross plots between instantaneous dominant frequencies extracted from the diffraction-image volume and amplitude envelope show that within the fluid- and hydrocarbon-saturated zones, the dominant frequency is approximately constant and in the low-frequency range between 25 and 33 Hz. However, outside the hydrocarbon zones, the dominant frequency increases as the amplitude envelope decreases. Maps of instantaneous dominant frequency extracted along the top and base of Eagle Ford Shale horizons reveal that areal distribution of low dominant frequency zones are coincident with high diffraction energy. Based on the foregoing, we conclude that by analyzing diffraction data, it is possible to infer likely sediment variation and fluid/hydrocarbon sweet spots within the Eagle Ford Shale and other shale resource plays.

Introduction

Faults and fractures present both problems and opportunities for exploration of and production from hydrocarbon reservoirs. They create problems when they occur in the reservoir caprock, allowing escape of hydrocarbon from the reservoir, but they provide opportunities when they act as conduits into the reservoir or when they act as trapping faults, preventing escape of hydrocarbon from the reservoir. Many petroleum reservoirs form in highly fractured rocks, where fracture properties such as density and orientation are crucial to reservoir economics.

Because of the key role that faults and fractures play in hydrocarbon exploration, several seismic attributes (e.g., similarity, coherence, curvature, ant track, diffraction imaging, and semblance) extracted from 3D seismic data have been developed to image them in the subsurface. Of these, diffraction imaging is unique because it not only