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High Resolution Diffraction Imaging of Small Scale Fractures in Shale and Carbonate Reservoirs

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Abstract

Current research in the field of seismic depth imaging has identified a new approach to image with super-resolution fractured zones, fault edges, small scale faults, pinch-outs, reef edges, channel edges, salt flanks, reflector unconformities, injectites, fluid fronts, caves and karst, and in general any small scattering objects, by using Diffraction Imaging as a complement to the structural images produced by reflection imaging. Diffraction Imaging is the imaging of discontinuities in the earth. Diffractions are the seismic response of small elements (or diffractors) in the subsurface of the earth, such as small scale faults, fractures, near surface scattering objects, and in general all objects which are small compared to the wavelength of seismic waves. We show results in different areas of the world, in fractured carbonates and unconventional shale reservoirs. Using Diffraction Imaging to identify areas with increased natural fracture density, which correlate with increased production, the reservoir engineers can design an optimal well placement program that targets the sweet spots and minimizes the total number of wells used for a prospective area.

Standard approaches to obtain high-resolution information, such as coherency analysis and structure-oriented filters, derive attributes from stacked, migrated images. Diffraction Imaging in comparison, acts on the pre-stack data, and has the potential to focus super-resolution structural information. Diffraction images can be used as a complement to the structural images produced by conventional reflection imaging techniques, by emphasizing small-scale structural elements that are difficult to interpret on a conventional depth image.

We show that operating in a migration framework on pre-stack data, using procedures which complement those used to enhance specular reflections, allows us to obtain higher resolution information, which is lost in conventional procedures. An efficient way to obtain diffraction images is to first separate the migration events according to the value of specularity angle, in a similar way to offset gathers; diffraction images are produced subsequently using post-processing procedures. The high-resolution potential is demonstrated by several case histories in carbonate reservoirs and unconventional shale like the Eagle Ford, which show much more detail than conventional depth migration or coherence.