New diffraction imaging method improves interpretation and structural framework resolution

Company's imaging approach can achieve a high-res interpretation of the subsurface

Contributed by Paradigm

It has been suggested that less than 50 percent of the subsurface information obtained from the seismic method is either underutilized or lost with standard imaging procedures. These procedures remain biased toward high-energy events defined by continuous reflectors or major discontinuities like large faults. This "specular" energy typically dominates the seismic data volumes used by interpreters. While image-processing techniques like coherency, fault-likelihood, and volumetric curvature can help recover or enhance discontinuities in the seismic data, they cannot recover the high-resolution and lower energy detail that has been masked or lost by standard processing and imaging procedures. These procedures make heavy use of integration (stacking) operators in the early stages of seismic image construction.

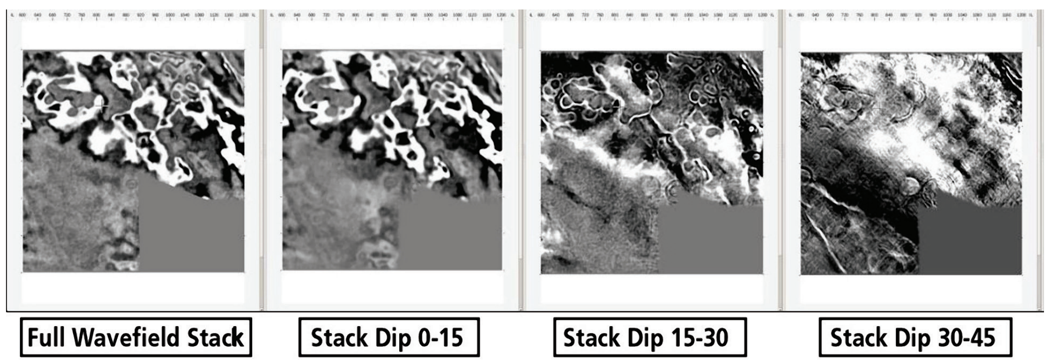
A measurable amount of energy associated with "high-resolution" features such as small faults, stratigraphic edges, and reservoir heterogeneities is generated from these subsurface scattering sources and recorded in the form of "diffraction" energy. The information encoded in diffraction energy can help explain reservoir compartmentalization, reservoir permeability, and reservoir performance. However, diffraction energy is generally masked by the dominant specular energy and irretrievably lost through the integration and stacking processes used during standard seismic processing and imaging. While standard procedures improve signal-to-noise ratios, they do not expose details that can resolve subsurface complexities, influence prospectivity determinations, or control reservoir behavior.

To recover high-resolution diffraction energy, special imaging procedures and operators are required. Paradigm has developed an imaging approach that retains the integrity of the recorded data in a form that can be used to achieve a high-resolution interpretation of the subsurface. Using the full-azimuth EarthStudy 360 imaging technology, input seismic data is first mapped into a full five-dimensional decomposition of the seismic wavefield for each imaging point. Mapping is carried out with a point diffraction ray-tracing operator that shoots rays from the imaging point equally in all directions. It forms a system of incident and scattered ray pairs in which data events are imaged and decomposed into two complementary full-azimuth angle gathers with *fully sampled directivities* and reflectivities. Decomposition is performed in a special reference system (local-angle domain) in which energies associated with directivity and reflection angles and their respective azimuths are "binned" for subsequent processing and interpretation.

The power of local-angle-domain diffraction imaging is that the images are computed from full-azimuth prestack data based on a visible discrimination of continuous (specular) and discontinuous (diffraction) energy at every depth point of every common-image gather. By performing this process in the full-azimuth local-angle domain, energy associated with high-resolution diffraction events is preserved. Once preserved and isolated, the diffraction energy can be enhanced with various signal-processing methods, and the resultant diffraction image volumes can be incorporated into the mainstream interpretation process.

The implementation allows interpreters to interact with the full-azimuth gathers to create the desired operator, proportional to the subsurface imaging objective. Small faults, natural fractures, stratigraphic edges, corner points, and selective structural or stratigraphic dips can be enhanced, even in the presence of strong specular energy.

Diffraction image energy can be further enhanced with seismic attributes like "fault likelihood," which are designed to thin faults to a few samples and only keep the fault lineament. The fault-enhanced seismic volume includes a rich set of new fault lineaments that can be incorporated easily into the structural framework by automatically propagating the fault surfaces in chronostratigraphic space. The solution is based on the UVT Transform, a paleo-geographical transform whose theory has been published extensively and implemented in Paradigm's SKUA subsurface modeling system. The system not only generates a geologically consistent model, it validates the interpretation data and allows the inclusion of interpretation details that are exposed in chronostratigraphic (paleo) space. In this process, faults are rotated onto a chronostratigraphic surface where automatic propagators can be used to effectively pick fault surfaces. The final model is a perfectly sealed structural model, including all faults and horizons, with no simplification of the data.



Diffraction imaging of a Barnett Shale data set using structural dip separation operators.

The workflow of full-azimuth diffraction imaging, fault-likelihood enhancement, chronostratigraphic fault interpretation, and fault framework creation has been applied successfully to shale resource plays and other faulted and fractured conventional reservoirs. The workflow enables rich information to be added to the reservoir description without compromising productivity or project timelines, enabling decision-changing outcomes. Visit Paradigm booth 3107 at the SEG Annual Meeting to learn more. ■