



EarthStudy 360[®]

Full-Azimuth Angle Domain
Imaging and Analysis



EarthStudy 360

A New World of Information for Geoscientists

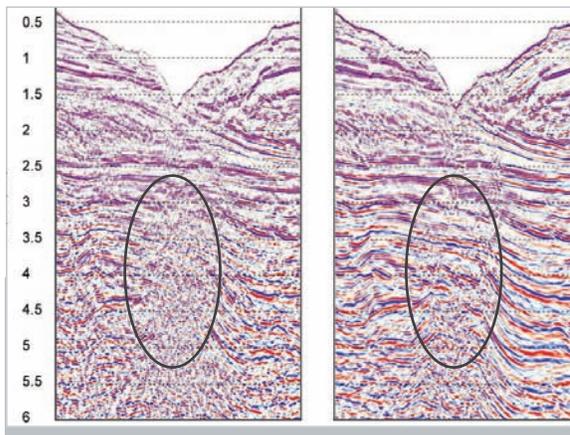
Expanding the Frontiers of Subsurface Exploration

Paradigm® EarthStudy 360® is an innovative new system designed to deliver to both depth imaging experts and interpretation specialists a complete set of data that enables them to obtain accurate subsurface velocity models, structural attributes, medium properties and reservoir characteristics. The system extracts unprecedented value from all modern and legacy seismic data acquisitions, especially those with wide and rich azimuth and long offset, in both marine and land environments.

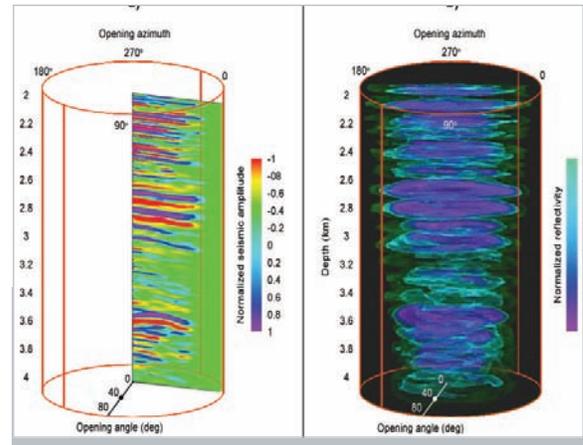
EarthStudy 360 is most effective for imaging and analysis in unconventional gas plays within shale formations and in fracture carbonate reservoirs. The system delivers highly accurate images from below complex structures, such as shallow low-velocity anomalies like gas pockets, subsalt, sub-basalt and high-velocity carbonate rocks. These result in optimal solutions for anisotropic tomography and for fracture detection and reservoir characterization.

Added Value for Geoscientists

EarthStudy 360 creates a wealth of seismic image data, decomposed into full-azimuth, angle-dependent reflection and directional (dip and azimuth) data components. These can be selectively sampled, creatively combined, dynamically visualized, and further processed to secure images of the subsurface. The images can reveal the information needed for velocity model determination, as well as provide details regarding the presence of micro-fractures, the orientation of faults and fractures, the influence of anisotropy, the directions of contributing illumination, the elastic properties of target reservoirs, and the boundaries of those reservoirs.



▲ Hidden structure revealed by EarthStudy 360

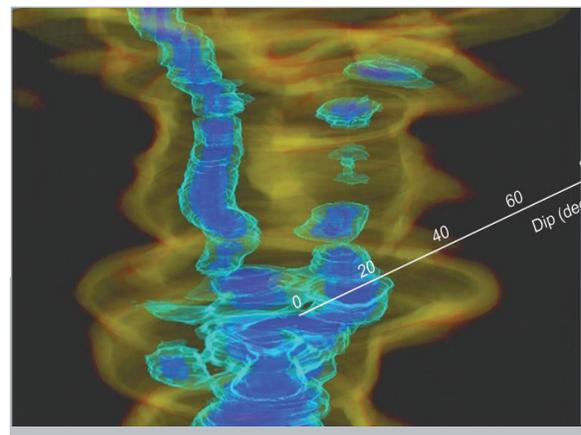


▲ Two views of 3D reflection angle gathers

Directional and Reflection Angle Gather Systems

EarthStudy 360 enables geophysicists to use all recorded seismic data in a continuous fashion directly in the subsurface local angle domain. This results in two complementary, full-azimuth, 3D angle gather systems: **Directional** and **reflection**.

Directional angle decomposition implements both specular and diffraction imaging with real 3D isotropic/anisotropic geological models, leading to simultaneous emphasis on both continuous structural surfaces and discontinuous objects such as small faults and small-scale fractures. Structural attributes at each subsurface point, such as dip, azimuth and continuity, can be reliably derived directly from the directional angle gathers.

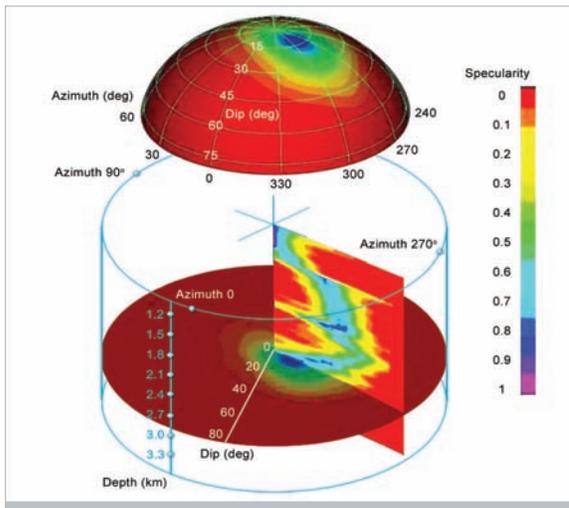


▲ Directional angle gather near geologic pinchout: Two specular signature directions at same location

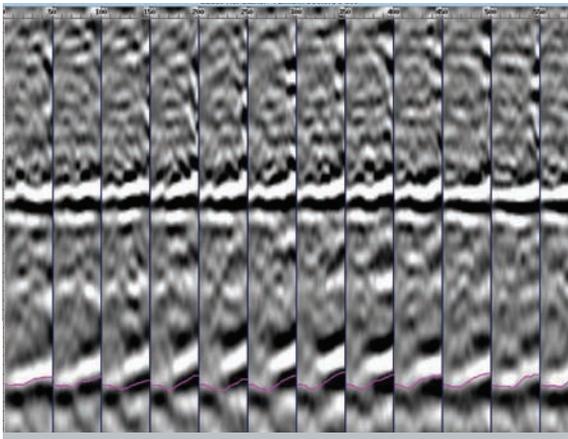
New Technologies for a New Age

Declining production in mature oil and gas fields is forcing upstream energy companies to explore areas of increasing operational and technical complexity. Existing solutions for extracting information about the subsurface geological model are limited, and there is a need to expand current technologies to include the acquisition of wide and rich azimuth seismic data. Paradigm is the first to meet this need with EarthStudy 360, a new invention designed to image, characterize, visualize and interpret the total seismic wavefield.

EarthStudy 360 reflection angle gathers provide “true amplitude” reflectivities that substantially increase the information needed to extract residual moveouts (RMO) and amplitude variations. The full-azimuth, angle domain RMO enables accurate velocity model determination (isotropy/anisotropy tomography). Full-azimuth, angle domain amplitude variations result in better reservoir characterization, with high-resolution elastic properties and high-resolution fracture determinations.



▲ 3D directional specularity gather



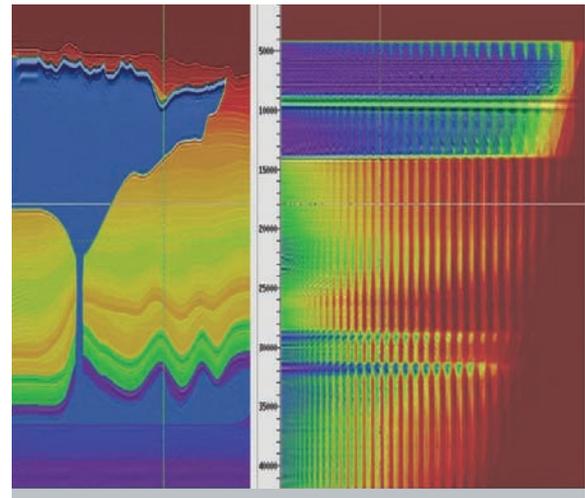
▲ Automatic RMO picking along 12 azimuthal sectors extracted from 3D reflection angle gather

EarthStudy 360 Imager

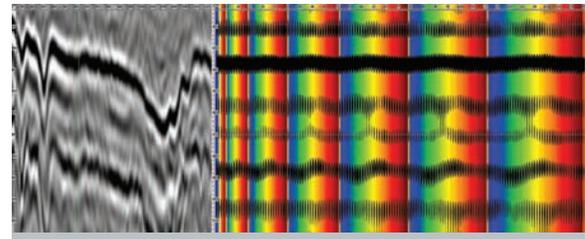
The **EarthStudy 360 Imager** is a cluster-based solution that efficiently uses the full recorded wavefield to generate 3D full-azimuth, directional and reflection angle gathers. The Imager can be utilized to provide fast, target-oriented solutions for local analysis, and can also be used for imaging on a regional scale.

EarthStudy 360 Tomography

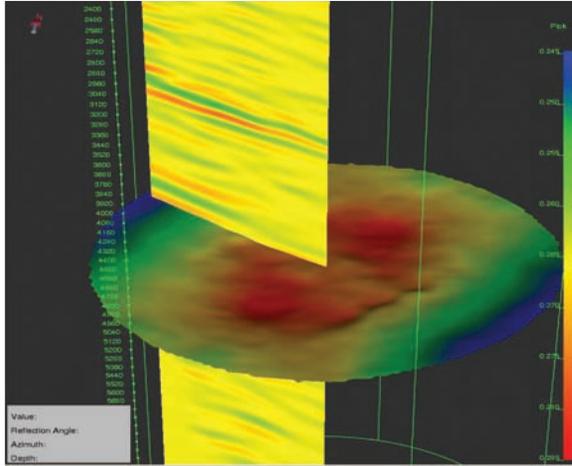
The tomography system uses input data extracted from EarthStudy 360 directional (directivity) and reflection (full-azimuth RMO) gathers to update the velocity model. The substantial increase in information about the subsurface improves accuracy and reduces uncertainty. This is especially important when determining anisotropy model parameters.



▲ Subsalt imaging and a selected reflection angle azimuth gather overlaid with illumination (Original data courtesy of Devon Energy Corporation)



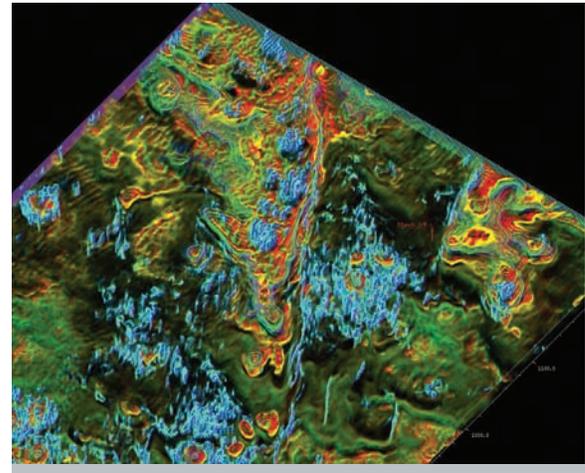
▲ 2D display of 3D full-azimuth reflection angle gather (Barnett Shale)



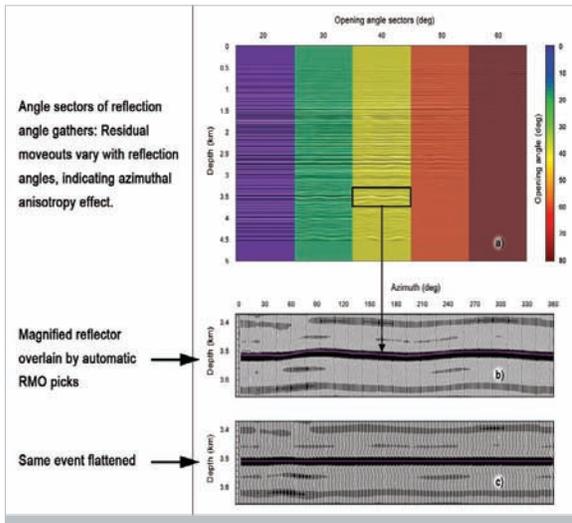
▲ Automatic RMO picking along 3D reflection angle gather

EarthStudy 360 as a Tool for Stress and Fracture Detection

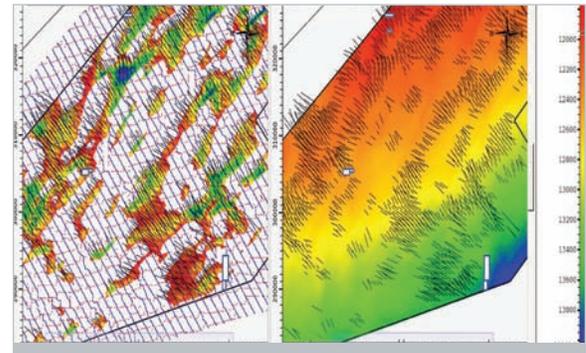
EarthStudy 360 uses both directional and reflection angle gathers to image and detect subsurface local heterogeneities such as small faults and fine fractures. Diffraction weighted stacks applied to directional angle gathers enable high-resolution imaging of the fracture system within the reservoir. Azimuthal-dependent residual moveouts (VVAZ) and amplitude variations (AVAZ), which can be automatically extracted from the full-azimuth reflection angle gathers, provide accurate information about the orientation and density of fracture systems.



▲ Fracture imaging



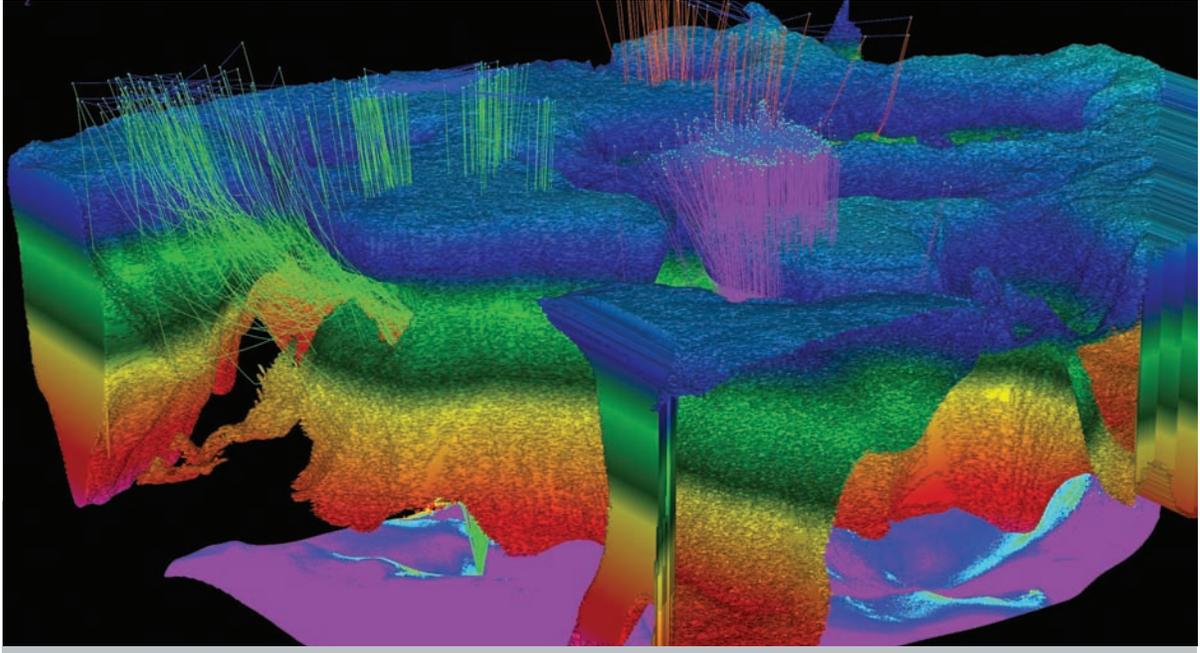
▲ Angle sectors of reflection angle gathers: Residual moveouts vary with reflection angles, indicating azimuthal anisotropy effect



▲ Fracture vectors (data courtesy of Seitel Ltd.)

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Geofizyka Torun
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With EarthStudy 360 we are able to deliver a much better product compared to standard 3D imaging. Reliable attributes estimated using EarthStudy 360 can help define sweet spots for unconventional prospects, as well as provide effective support to decisions about horizontal drilling and hydraulic fracturing. Together, these significantly reduce prospect uncertainty. Following our comprehensive and successful evaluation, in which we ran full-azimuth anisotropic imaging on the first 3D shale gas seismic survey in Poland, Geofizyka Torun now plans to process the next shale gas seismic project with support from Paradigm.



▲ Understanding subsalt uncertainty through illumination study

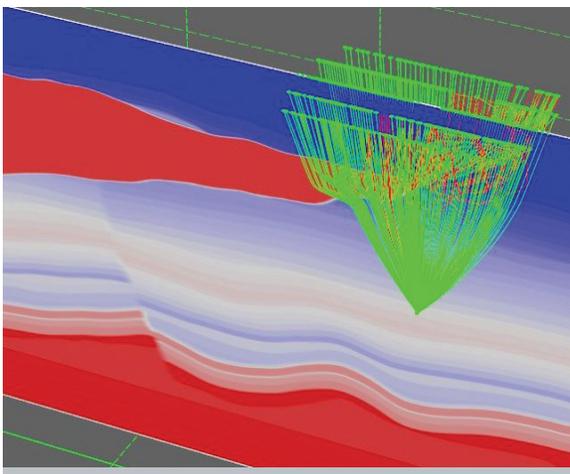
Orthorhombic Model Support

Running the EarthStudy 360 Imager with orthorhombic layer parameters allows users to fully validate the accuracy of their fracture analysis and improve imaging, in conventional and unconventional plays. This adds another level of confidence in the results, and results in better drilling decisions.

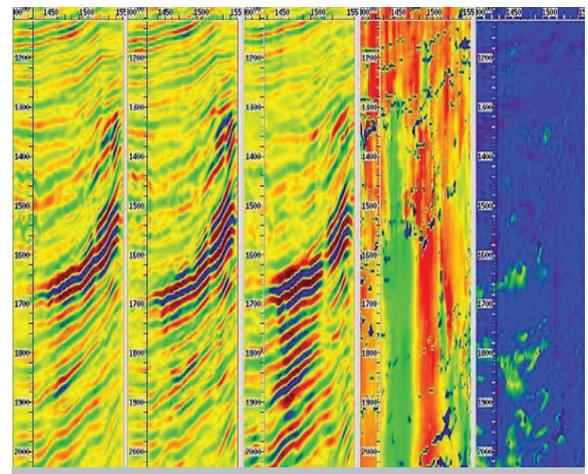
Illumination for Seismic Data Mining

The EarthStudy 360 Illuminator is an advanced seismic data mining tool that provides a previously unattainable breadth of knowledge about ray propagation in complex areas.

The Illuminator uses an enhanced, interactive ray tracing technology that both quantifies and qualifies the relationship between the surface acquisition geometry and the subsurface angles in targeted areas. Launched from the Paradigm SeisEarth® or GeoDepth® 3D Canvas, input for the Illuminator includes isotropic/anisotropic velocity models and optionally, data acquisition geometry. Interpreters can generate ray attributes, illumination and reliability maps to gain knowledge about the quality and integrity of the seismic image. A user who wants to know more about why certain areas have low reliability, has access to an extensive set of tools which deliver that knowledge. The results are displayed in a clear visual manner, simplifying even the most complex set of imaging characteristics.



▲ Two-point ray tracing in complex subsurface



▲ Full-azimuth reflection data (AVAZ attributes)

Features

- Support for isotropic and anisotropic models (VTI, TTI and Orthorhombic)
- Customizable to image specific exploration or development challenges, such as velocity determination and amplitude inversion
- Directivity-driven: Can run in preferred directions with respect to given background directivities (dip and azimuth)
- Beam steering: Performs tapered local slant stack, and migrates only energetic events
- Imaging with local slant stack events, providing significant multiple suppression
- A collection of all the display tools that enable visualization of EarthStudy 360 gathers: Velocity Navigator, 3D Canvas and 3D Gather Visualizer
- Generates optimal data for tomographic velocity updates and amplitude analysis
- Includes Paradigm 2D/3D CRAM® for generating conventional reflection angle gathers with no azimuth dependency
- Support for Ocean Bottom Cable acquisition data
- Support for Q Compensation, improving resolution, amplitude balancing and image quality by compensating for dissipation and attenuation effects

Interoperability

All Epos-based applications enable interoperability with third-party data stores, including:

- OpenWorks® R5000
- GeoFrame® 2012

System Specifications

- All 64-bit, for x64 architecture processors
- Red Hat® Enterprise Linux® 6.5 and above, 7.0 and above

The Paradigm Advantage

- Full-azimuth angle imaging and analysis maximize knowledge from seismic data.
- Optimizes ROI for deep water, unconventional shale resource plays and fractured carbonate reservoirs.
- Extracts unprecedented value from all modern and legacy seismic data acquisitions, notably those with wide and rich azimuth and long offset.
- Delivers highly accurate isotropic/anisotropic velocity models, especially in complex subsurface areas.
- Delivers high-resolution information about principal reservoir properties.
- Extends the capabilities of leading Paradigm processing, imaging and analysis systems.

www.pdgm.com

Original data courtesy of Devon Energy Corporation.

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