High-Resolution Seismic Imaging in Shale Plays

Two methods boost confidence in prospecting and field development decisions.

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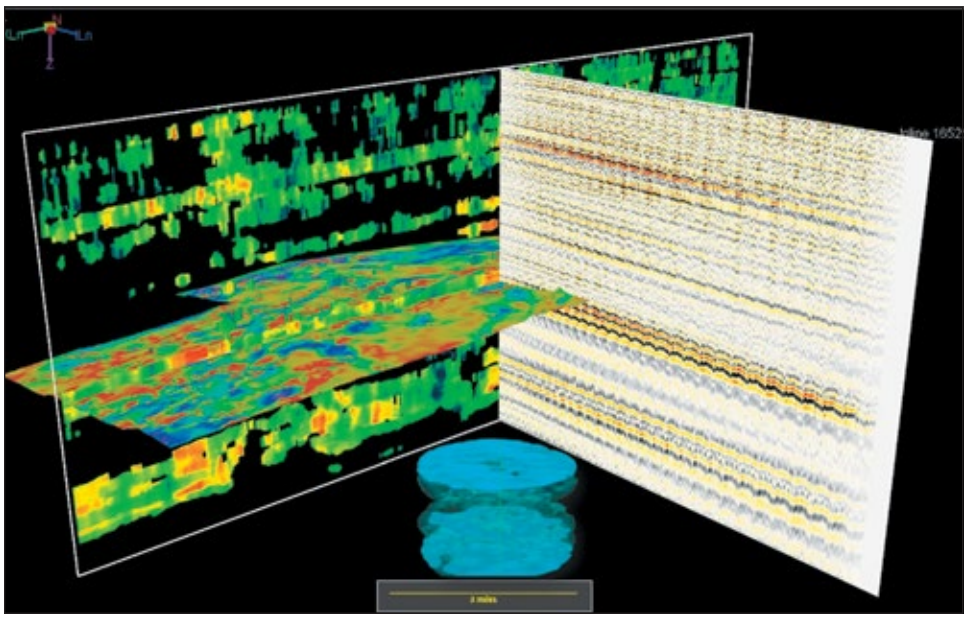
Ten years ago the role of surface seismic data had limited application and use for shale operators, as drilling engineers moved at unprecedented speed to cover existing and newly acquired acreage. This capital-intensive drilling engineering and completions campaign required continuous optimization at all levels of operation to both drive down costs and optimize well performance. As operators gained more experience in their shale assets with these pervasive drilling programs, their knowledge base of the subsurface grew at a similar pace, with as many questions as answers. Attention subsequently turned to the details of the subsurface, with a specific focus on spatial and vertical variations in total organic carbon (TOC), mineralogy, facies, natural fractures and stresses. Additionally, planning and steering of long and longer laterals required precision depthing of shale lithozones over large acreage positions.

While seismic data on its own cannot provide unique answers to all of these, recent advances in seismic acquisition and imaging methods provide game-changing solutions that can contribute dramatically to a geoscientist's understanding of shale distribution and behavior. The deliverables from these imaging methods not only have relevance for sweet-spot identification, but they also provide useful stress and fracture information for drilling engineers in their planning and active steering.

Emerson has invested heavily in shale geophysics and has developed and adapted seismic imaging methods to solve specific challenges in shale plays all over the world. Two methods—full-azimuth (FAZ) imaging in the Local Angle Domain (EarthStudy 360) and holographic imaging—have enjoyed tremendous success in influencing prospecting and field development decisions by improving azimuthal and vertical resolution to levels required in shale operations.



The image shows fracture determination using EarthStudy 360 full-azimuth reflection angle gathers. (Image courtesy of Emerson)

High-resolution FAZ seismic imaging

Imagine generating seismic data that sample the subsurface in situ rather than from the surface, that recover full (360-degree) azimuth data without sectoring or approximation, and that illuminate the subsurface in all angles and orientations. These properties of EarthStudy 360 are achieved by using a rich bottom-up diffraction ray tracing engine to create a five-dimensional organization of the prestack seismic data. These data in turn are used to create two types of 3-D angle gathers. The first, FAZ reflectivity, is the borehole equivalent of full waveform acoustic logs. The second, FAZ directivity, is the equivalent of dip meter or image log.

With these two data structures, shale geoscientists can create stable and high-resolution fracture and stress maps for all types of fracture conditions (including orthorhombic), diffraction images that can identify low energy faults and stratigraphic edges, and high-resolution anisotropic velocity models that can

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offshore Mexico's Yucatan revealed circular anomalies that led to the discovery of the Chicxulb crater formed by a large meteor impact that is believed to have led to the demise of the dinosaurs, he said.

Exploration geophysics contributes to that prosperity by conducting the energy resource assessments necessary to determine the economic suitability of those resources. The ways in which those assessments are conducted have improved over the years, thanks in part to advances in technologies and in understanding the complexities of the subsurface.

Dr. Walter Guidroz, coordinator for the Energy Resources Program for the U.S. Geological Survey (USGS), delivered the opening session keynote on how the agency's approach to its unconventional play analysis has evolved. The USGS is responsible for the accurate assessment of the public's resources.

"Change is the only constant in life," he said. "The petroleum industry has evolved from conventional plays that started many decades ago to the unconventional play analysis that we now see as part of the normal maturation process. But even in the analysis of unconventional plays, things have changed. We've had to adapt to that at the USGS."

Part of that adaptation includes recognizing the impact the evolution of new technology has had on the recoverability of the resource. For example, Guidroz cited a 2003 USGS assessment of the Marcellus Shale that it contained 1.9 Tcf of undiscovered, technically recoverable natural gas. In 2011, a reassessment was conducted, with the USGS determining that that the Marcellus Shale contained about 84 Tcf of undiscovered, technically recoverable natural gas. The difference in numbers was due to the "new technology that increased the EUR for a given well," he said, citing more efficient hydraulic fracturing technologies and improvements in horizontal drilling techniques as enabling that increase in the resource assessment. The USGS is currently performing a new reassessment of the Marcellus Shale, with results expected to be released in late 2019 or early 2020, he said.

The USGS, Guidroz noted, is using the present as an analogue for the future by embracing artificial intelligence and machine learning techniques. To better identify the subsurface, the USGS is using current production data from unconventional wells to better determine EUR and to explore spatial patterns in data. ■

INDUSTRY NEWS

New Data Center Completes Global Network

This year, DownUnder GeoSolutions powered up its geophysical cloud service, DUG McCloud. DUG's newly opened Houston facility joins the other DUG data centers to form the full DUG McCloud global network, the first global cloud purpose-built for high-performance computing (HPC) and tailored to the oil and gas industry.

The first DUG McCloud data hall at Houston's Skybox Datacenters will house a 250-petaflop (single-precision) machine, known as Bubba. DUG already has a second, identical data hall with plans in place to commence buildout in late 2019. Joint capacity of the two data halls will be approximately 650 petaflops.

IMAGING
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resolve some of the most challenging overburden conditions, like those observed in the Permian Basin. These high-resolution velocity models are generated with full azimuth tomography, a solution that can incorporate well markers, check shots and vertical seismic profile data to generate velocity models suitable for precision depthing.

High-resolution holographic imaging

The second imaging advancement, holographic imaging, overcomes the resolution limitations of traditional seismic processing and imaging workflows. Developed by Dr. Norman Neidell, this method draws on the principles of holography and decouples seismic image sampling from acquisition sampling, where the image is a composite of voxels representing point reflectors or diffractors. The holographic seismic image assembles all the contributions of the captured wavefield for each voxel, responding to the subsurface properties rather than the source properties or a propagating wavelet.

When combined with a simple composite inversion and extended visual dynamic range displays, the holographic seismic image reveals its full interpretation power, as it's able to resolve the details of shale lithozones, including the organic-rich Eagle Ford layer and the brittle Woodford shale layer. Such detail allows geologists to select or confirm well plans and enables drilling engineers to steer wells within formation with confidence.

These shale geophysics technologies and results will be featured in Emerson's booth 1433 in Tuesday's Lunch and Learn session. ■

COUNCIL
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wait until the start of the next year to become members and receive benefits.

The second proposed bylaws amendment proved more contentious. This set of adjustments sought to eliminate the requirement that applicants for active membership submit education and experience details to support their eligibility. This proposal was similar to one that did not gain council endorsement last year, a fact noted by three attendees during the discussion period. The SEG Board of Directors submitted the proposed amendment from the view that it failed last year because some on council thought mistakenly that it reduced qualifications for active membership. After a good deal of discussion, Council Chair Gustavo Carstens called for a vote, and the proposed amendment failed to achieve the two-thirds majority approval necessary to continue on to a vote of SEG Active and Associate Members.

The third proposal of the day—to properly define the term "Voting Members" within the SEG Bylaws—was the quickest to pass and garnered no discussion before the council voted overwhelmingly in its favor. The amended bylaws would capitalize the term "Voting Members" throughout, and a definition would clearly distinguish Voting Members (Active, Honorary, Life, Emeritus and Associate Members) from non-Voting Members (Student, Junior and Corporate Members).

The final proposed amendment considered by the council on Sunday sought to define clearly the process for and timing of council action on proposed changes to the bylaws. There are conflicting interpretations of current bylaws regarding whether the council may consider bylaws amendments only at its meeting during the SEG Annual Meeting or also during any other council meeting, including meetings conducted via teleconferencing or web conferencing. The amendment as proposed would empower the council to consider bylaws changes at any council meeting in which a quorum is established.

This fourth proposal ultimately passed but only after the wording was further amended to make it clear that all SEG members, not just council members, would be notified of all council meetings and that any interested SEG member would be able to participate in any council meeting with the privilege of speaking but not voting. The further rewording of the amendment helped allay concerns about a lack of member participation, and therefore transparency, during council meetings held at times other than during the SEG Annual Meeting, all of which are entirely online.

The three amendments endorsed by the council will be submitted by ballot within 60 days to Active and Associate Members, and those amendments that are affirmed by a majority of those members will be enacted.

Prior to the discussion of proposed bylaws amendments, SEG President Rob Stewart gave a brief report on the state of the society highlighted by news of a positive budget in 2019, the pending sale of SEG real estate in Tulsa, Okla., and expansion of the society's presence in Houston and Kuala Lumpur. Carstens followed with a report as council chair in which he pledged to work with council members to improve the body's outreach and value to SEG members. ■