SEG19
SAN ANTONIO, TX
15-20 SEP 2019
INTERNATIONAL EXPOSITION
89TH ANNUAL MEETING

DAILY NEWS

TUESDAY 17 September 2019

HARTENERGY | THE OFFICIAL SHOW DAILY PUBLISHER OF THE SEG INTERNATIONAL EXPOSITION AND 89TH ANNUAL MEETING

Prosperity, Serendipity and Unity

Exploration geophysics contributes to economic growth and unification of global societies.

BY JENNIFER PRESLEY, EXECUTIVE EDITOR

Prosperity has long propelled humans forward into unknown environments to seek out the resources to make their lives more comfortable. The Earth's resources have long been the foundation of that prosperity, noted 2018-2019 SEG President Dr. Robert Stewart in his presidential address during Monday's opening session for the SEG International Exposition and 89th Annual Meeting in San Antonio, Texas.


Dr. Walter Guidroz

Early-day explorers like Columbus and Magellan sailed the seven seas, searching for resources, looking for ways to expand and increase prosperity, he noted. Look to the gleaming towers of glass present in the downtown areas of many cities to see modern day examples of how energy applied to a raw resource (sand) elevated prosperity to new heights.

Energy consumption, and therefore its demand, will continue to increase, he said.

"We are going to use more energy than we think," said Stewart. "There is no lack of demand for increased prosperity."

There are unexpected benefits of resource exploration or, as Stewart called it, "the serendipity of searching," with the development of technologies like Auto Tune and the discovery of unknown places like the Kidson Basin offshore Australia. The search for hydrocarbons

See **PROSPERITY** continued on page 15

SEG Council OKs Three Bylaws Amendments

Proposal to simplify application process fails for second time.

BY SEG STAFF

During a meeting on Sunday afternoon during the SEG Annual Meeting, the SEG Council passed three proposed SEG bylaws amendments—one that would institute an anniversary dues cycle for members, a second seeking to clarify which members have voting rights, and a third to update council procedures. Meanwhile, a proposed amendment aimed at simplifying SEG membership applications failed.

The first proposed bylaws amendment presented before the council on Sunday passed convincingly and with little discussion prior to the vote. This set of bylaws changes would change the renewal dates of members to the anniversaries of when they joined. Currently, renewal dues are owed at the start of each calendar year, regardless of the date on which the member joined. Going forward, new members' dues would be due on the anniversary of the members' join date. A major benefit of this amendment would be that new members joining in the fourth quarter of the year no longer would have to

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SEG19 SAN ANTONIO, TX 15-20 SEP 2019 INTERNATIONAL EXPOSITION 89TH ANNUAL MEETING

SCHEDULE OF EVENTS

All events in conjunction with SEG 2019 will be held at the Henry B. Gonzalez Convention Center in San Antonio, Texas, unless noted otherwise. For a complete schedule of events visit *seg.org/Annual-Meeting-2019/Schedule*.

Tuesday, Sept. 17

7:30 a.m. to 6 p.m. ..... Registration and Self-serve Badge Kiosks (Main Lobby)
7:30 a.m. to 6 p.m. ..... SEG Book Mart (Main Lobby)
8:30 a.m. to 5:10 p.m. ... Technical Program Oral Sessions (Rooms 214-305)
9 a.m. to 11 p.m. ..... Plenary Session: Digital Transformation in Petroleum Geophysics: What Impacts are We Seeing? (Stars at Night Ballroom B1)
9 a.m. to 12 p.m. ..... Applied Science Education Program (Stars at Night Ballroom B4)
9 a.m. to 1 p.m. ..... SEG Evolve (Room 225D)
9 a.m. to 6 p.m. ..... SEG Exhibition (Exhibit Hall 1-3)
9 a.m. to 6 p.m. ..... Student Lounge (Exhibit Hall, SEG Avenue)
9:20 a.m. to 4:20 p.m. ... Technical Program Poster Sessions (Exhibit Hall, Hall 1)
11:30 a.m. to 1 p.m. ..... Latin American and Caribbean Luncheon (Room 220)
12:05 p.m. to 1:05 p.m. . Near-surface Panel Discussion: Solving Near-surface Problems with Geophysics and Engineering (Room 221A)
1:50 to 5:25 p.m. ..... Plenary Session: Latin America and the Caribbean: Business Opportunities and Challenges (Stars at Night Ballroom B1)
4:30 p.m. to 6:30 p.m. ... Emerging Professionals (EPIC) Happy Hour (3rd Floor Terrace)
6:30 p.m. to 7:30 p.m. ... Honors and Awards (Grand Hyatt)
7 p.m. to 10 p.m. ..... Near-surface Geophysics Technical Section Reception (Iron Cactus Restaurant)
9 p.m. to 12 a.m. ..... Presidential Jam (Grand Hyatt)

Wednesday, Sept. 18

7:30 a.m. to 5:30 p.m. ... Registration and Self-serve Badge Kiosks (Main Lobby)
7:30 a.m. to 6 p.m. ..... SEG Book Mart (Main Lobby)
8 a.m. to 10 a.m. ..... Members-only Breakfast: Meet, Eat and Greet (Room 220)
8:30 a.m. to 10:35 a.m... Plenary Session: Improving the Business Model of Land Seismic and Processing in the U.S.: Technology, Quality, Economics (Stars at Night Ballroom B1)
8:30 a.m. to 5:10 p.m. ... Technical Program Oral Sessions (Rooms 214-305)
9 a.m. to 4:30 p.m. ..... SEG Exhibition (Exhibit Hall 1-3)
9 a.m. to 4:30 p.m. ..... SEG Student Lounge (Exhibit Hall, SEG Avenue)
9:20 a.m. to 4:20 p.m. ... Technical Program Poster Sessions (Exhibit Hall, Hall 1)
12 p.m. to 1 p.m. ..... Delegate Luncheon (Exhibit Hall 1-3)
1:50 p.m. to 3:55 p.m. ... Plenary Session: The Changing Business Climate of Marine Geophysics: Roadmap to the Future (Stars at Night Ballroom B1)
5:30 p.m. to 8:30 p.m. ... Wrap-up Party (Convention Center: The LDR and Grotto)

Visit Society of HPC Professionals in the Digital Arena

CONTRIBUTED BY THE SOCIETY OF HPC PROFESSIONALS

With so much emphasis on the digital revolution at this year's SEG Annual Meeting, one area of the exhibit hall sure to see heavy traffic is the Digital Arena, featuring the Society of HPC Professionals.

A charitable service-based nonprofit organization, the Society of HPC Professionals is set up to educate and connect the high-performance computing (HPC) user community to state-of-the-art technology for the purpose of optimizing business processes and workforce advancement. The organization's technology focus includes artificial intelligence, cloud computing, data science, deep learning, machine learning and visualization utilized in applications as diverse as manufacturing and engineering, financial services, life sciences, energy, academia and government.

The Society of HPC Professionals delivers monthly lunch-and-learn events focused on the technologies and markets described above. These are held the fourth Thursday of the month at the University of Houston. The events are also streamed, so those unable to attend in person can view remotely. The lunch-and-learn streams and presentation materials are also made available for download at a later date from the society's website.

The society holds an annual meeting the first week of December when sponsors (including Intel, Red Hat, AWS, PCPC Direct, Schlumberger, Unique Digital and Hewlett Packard Enterprise's Data Science Institute at the University of Houston), members and technology leaders can meet and discuss topics important to the HPC marketplace. More information is available at https://hpcsociety.org and in the society's booth 1851. ■

Attendees began gathering early on Monday morning as SEG's 89th Annual Meeting got underway at the Henry B. Gonzalez Convention Center in San Antonio. (Photo by Jennifer Presley)

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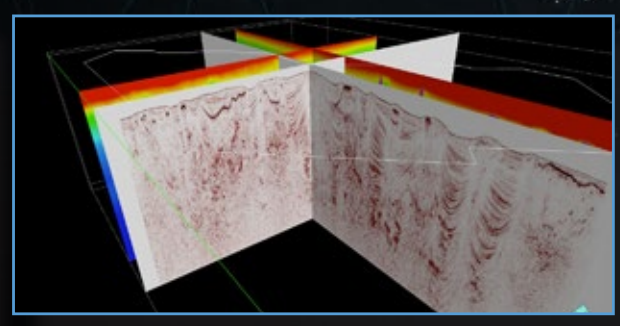
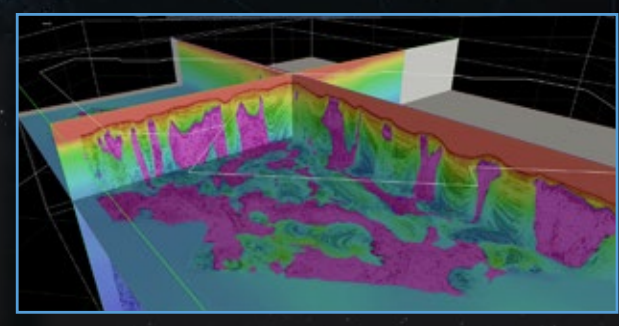
Identify with the **GAIA Earth** workflow.



Screen with the **GAIA Viz** workflow.



Evaluate with the **GAIA Pro** workflow.

GAIA

Digital Subsurface Platform

WesternGeco

Augmenting Reservoir Characterization with Machine Learning

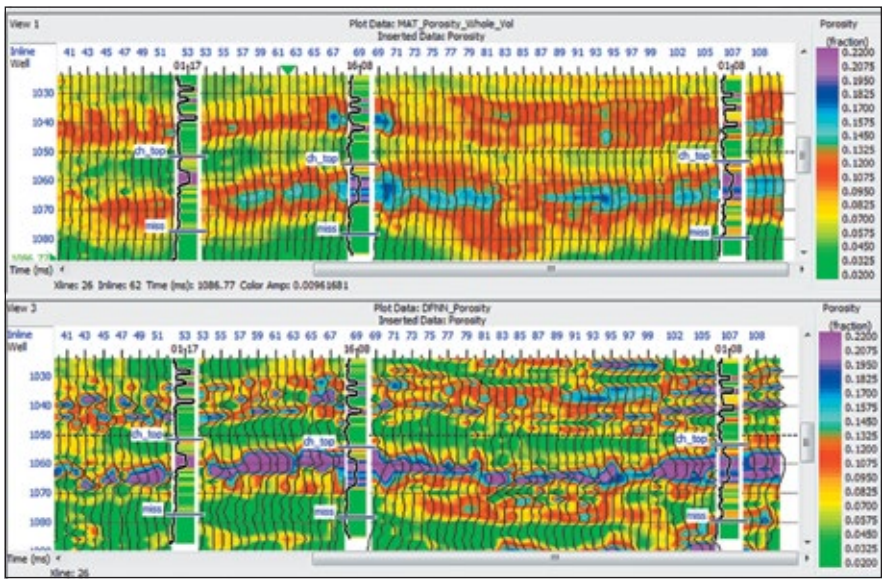
Geoscientists are being empowered with the latest machine learning toolkit and innovative software on the Azure Cloud.

CONTRIBUTED BY CGG

Machine learning continues to make the headlines at industry events this year with dedicated workshops and technical sessions. While machine learning offers opportunities to potentially revolutionize geoscience workflows, not everyone is an expert practitioner capable of taking full advantage of the latest developments.

CGG GeoSoftware has a well-established track record of taking new technologies and making them accessible to the industry, for generalists and experts alike. As the potential of the rapidly evolving machine learning toolkit became apparent, it became a priority to "democratize" it through the software. The result is a machine learning ecosystem, which provides open access to data and support for the use of external Python scripts across the whole suite of products, from petrophysics to advanced interpretation and seismic reservoir characterization.

Python-scripted machine learning lets experts and data scientists completely customize reservoir characterization workflows with their own proprietary code. For the geology and geophysics generalist, carefully selected pre-built recipes using intuitive graphical interfaces augment their workflows. Many tasks can now be completed more quickly and with more detailed results, for example, well log editing and petrophysical analysis, facies classification and reservoir property prediction. Analytical tools such as Gaussian mixture modeling clustering and hierarchical agglomerative clustering are available for routine use. Results can be easily understood by using an array of readily available visualization tools. The same Python Ecosystem will be accessible in HampsonRussell and Jason products in the coming releases and is enhanced to include new data types such as seismic volumes, seismic attributes along wellbores and interpretations.



Porosity predictions from HampsonRussell Emerge compare a traditional multilinear regression (top) to the prediction from a deep feed-forward neural network (DFNN) (bottom). The DFNN result shows a more detailed prediction of the reservoir with improved lateral continuity and a better match at the wells. (Image courtesy of CGG)

Twenty years ago, before "machine learning" was a commonly used term, HampsonRussell released the first commercial Neural Network-based approach for reservoir characterization. In this pioneering launch, HampsonRussell's Emerge reservoir attribute prediction module included multilinear regression, the probabilistic neural network and the single layer feed-forward neural network. These techniques continue to be used for predicting

See **RESERVOIR** continued on page 13

NEW

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Getting Closer to the Reservoir with Rock Physics Integration

Recent acquisition adds capabilities and data atlases to company's portfolio.

CONTRIBUTED BY PGS

Following the recent acquisition of the main assets of Rock Solid Images (RSI), PGS is adding rock physics, real-time seismic amplitude versus offset (AVO) modeling capabilities, and data atlases to its portfolio. The combination of GeoStreamer technology with RSI rock physics tools and atlases offers significant benefits when integrating seismic with well data, for example in demonstrating AVO compliance. PGS will also use the technologies to reinforce its 4-D feasibility and modeling of rock properties, calibrating GeoStreamer seismic with conditioned well data and known production scenarios.

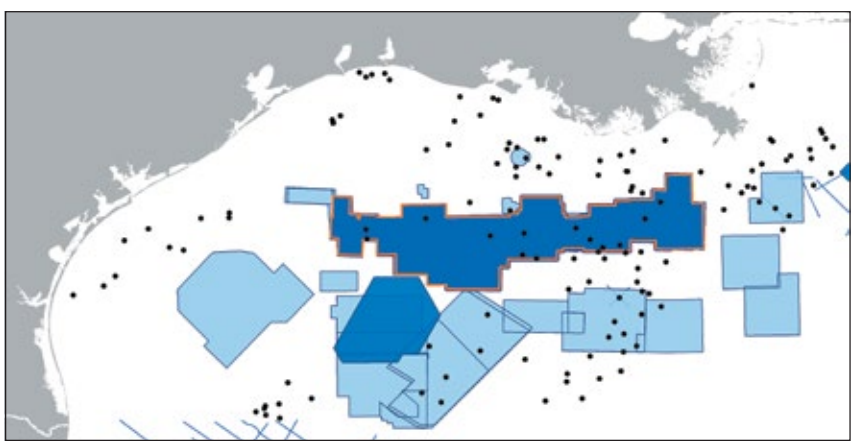
Executive vice president of New Ventures Berit Osnes says PGS will integrate well-based rock physics data in its MultiClient data library, offering the interactive rock physics atlas browser *rockAVO* as a MultiClient product. The current suite of rock physics atlases is a good fit with the PGS seismic data library, especially in the U.S. and Europe, with wells in the Gulf of Mexico (GoM), the Barents Sea, the Norwegian Sea, the North Sea and the U.K. Central Graben.

Unlocking reservoir properties

Rock physics is the link between seismic response and geological properties. It explains how rock properties like density, porosity and fluid fill influence seismic velocities and amplitude response at the well location.

Rock physics properties vary from basin to basin, and from stratigraphic interval to interval. For each, a separate model or rock physics template is required that relates seismic parameters to earth properties.

"PGS has ample access to the seismic side of this template. We've now added the geological part that comes from well data and a proven software tool to deliver fully interactive, well by well, rock physics-AVO modeling," Osnes says.



Overlap and integration of RSI well data with the PGS data library in the GoM is shown. (Image courtesy of PGS)

Expanding rock physics products in support of exploration

Regional *rockAVO* atlases for Europe and the GoM will be expanded to new areas, such as West Africa. At the exploration stage, combining regional rock physics atlases with seismic data library coverage will permit fuller and faster calibration of zones of interest and analog screening.

"Rock physics and real-time, dynamic seismic AVO modeling, with regional atlases and local studies targeting individual wells, will offer valuable additions to the PGS MultiClient product portfolio in key basins. This will enable our clients to carry out rapid screening for analogs and scenario testing of lithology, fluid, and porosity. New services will expand on established RSI workflows and technologies," Osnes explains.

Calibrating well data to 4-D seismic

Matching 4-D well modeling to 4-D seismic will offer further proof of the AVO compliance and imaging integrity of PGS seismic data.

4-D well AVO modeling can be integrated with seismic gathers, using the *rockAVO* interactive software, and PGS can now deliver enhanced 4-D feasibility studies and scenario modeling of reservoir characteristics, like saturation and pressure changes.

"Interactive AVO modeling enables rapid testing during both processing and interpretation, potentially improving the quality of project deliverables," says Allan McKay, vice president of 4-D Technology and Business Development.

QI advantage

The RSI acquisition will also strengthen PGS' quantitative interpretation (QI) capability, according to PGS' Global QI Manager Cyrille Reiser.

"Successful QI begins with an audit of available well log and seismic data, then data conditioning and rigorous quality control. The objective of QI is to estimate elastic seismic attributes within their proper geologic context. Rock-physics-driven QI techniques combining *rockAVO*, prestack AVO compliant seismic data and additional post-seismic inversion technologies will enhance the ability of PGS clients to predict rock and fluid type accurately during reservoir review and prospect analysis," he says.

"PGS has the finances and global reach to enable growth of these real-time dynamic rock physics products on a whole new scale, and the added synergies of the PGS data library mean this area has a very exciting future," Osnes says. ■

Deep Learning for Seismic Interpretation

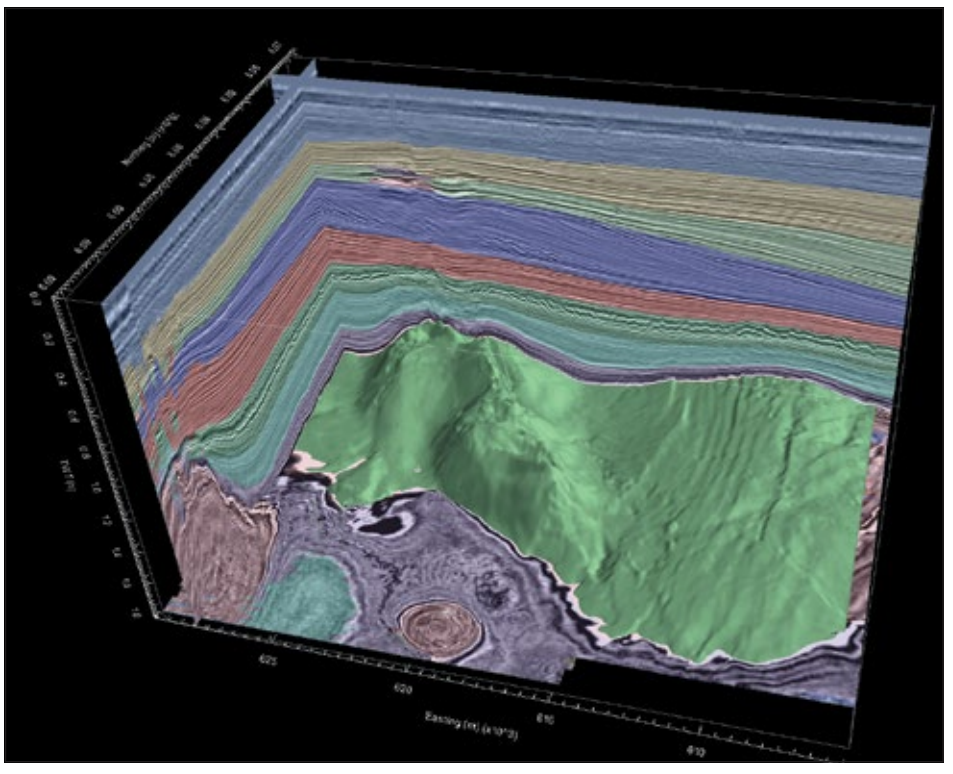
Demonstrating the potential AI brings to seismic interpretation.

BY BEN LASSCOCK, ENTHOUGHT

An interpreter can transform a very limited set of labeled regions within a seismic volume into a 3-D model of the volume using an AI. Horizons are then automatically extracted across the 3-D volume, with 3-D metrics of uncertainty created to aid in the ongoing interpretation.

The first step to building the AI is to define a consistent "taxonomy" for what the interpreter plans to identify. In this example, the taxonomy includes a region bounding the salt, a chaotic zone, a clinoform and a set of continuous regions. We then took the F3 3-D seismic volume* and consistently labeled a small set of 5 inlines (<1% of the available data) according to this label taxonomy.

Next, we train a deep-learning model to replicate this interpretation given the subset of labeled inlines, then make a prediction across the entire volume. The output of this procedure is a collection of 3-D volumes, each containing the probability of a particular label. The most likely label is selected at each point in the volume.



We then iterate, correcting any errors we see on an additional set of 5 inlines that we use to continue training the model, making one 3-D final prediction. Note that very little work labeling was required after creating the initial model.

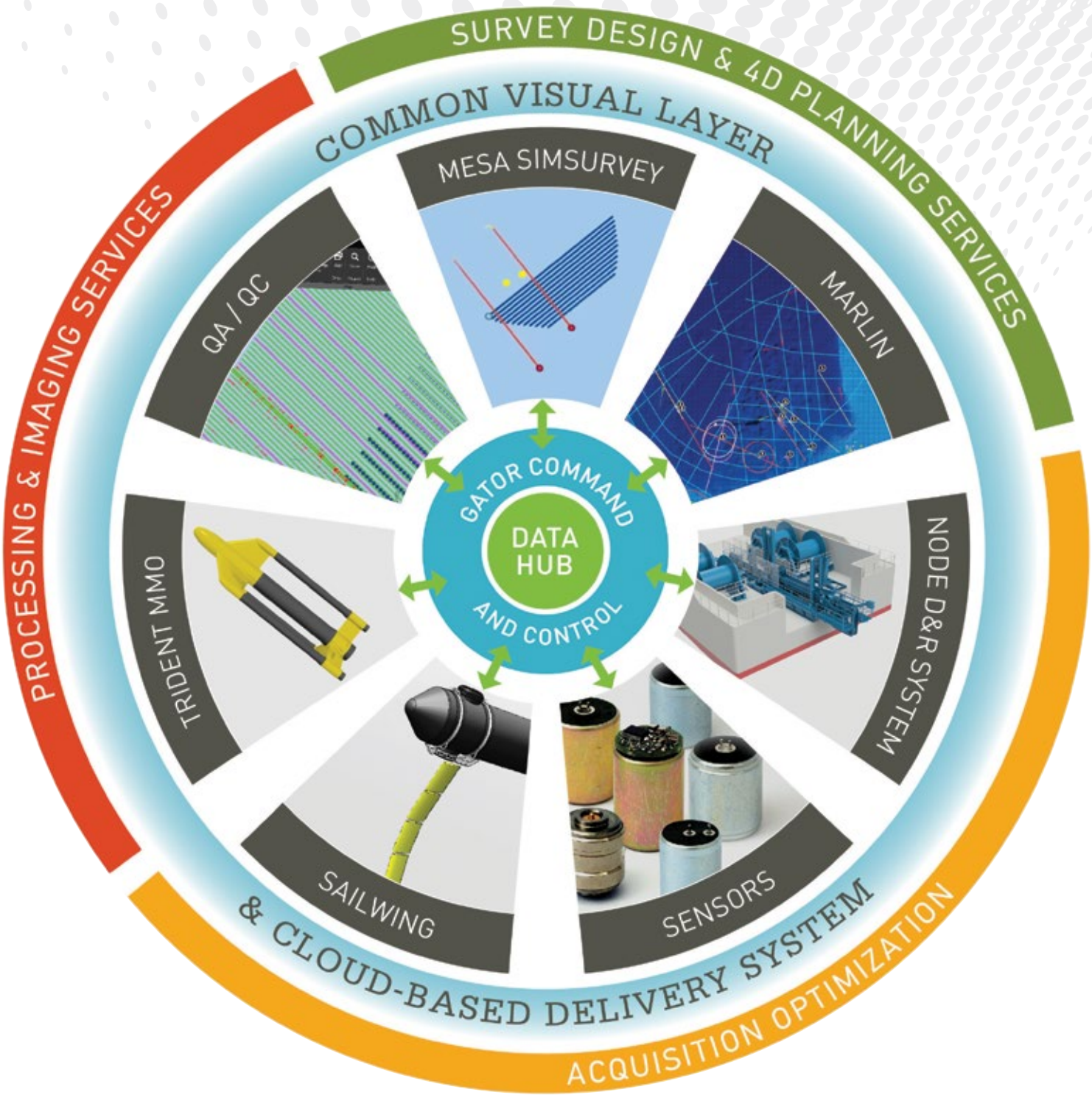
A horizon (in the associated figure) delineating the region bounding the salt is derived from the resulting label probability volumes and processed. No further human interaction was required to extract the horizon after retraining and prediction.

The accuracy of the technique and minimized use of expert time demonstrate the potential AI and deep learning bring to seismic interpretation.

Visit the Enthought booth to try out the technique. ■

This figure shows cross-sections through the F3 3-D seismic volume* with sequence labels predicted using an AI, overlaid in color. A machine learning method is used to derive a horizon on top of the "Salt" label, detailing the complicated geology immediately bounding the intrusion of the salt. The AI is initially trained by an interpretation on 5 inlines (<1% of the available data). An initial prediction is then made on an additional 5 lines; any errors are corrected, and the AI continues training on the updated lines. Horizons are then extracted automatically from the resulting 3-D volume(s) of predicted label probability. **The F3 3-D seismic volume was obtained from the "dGB Open Seismic Repository" and used under the Creative Commons (3.0 BY-SA) license. Augmentation of this data using deep learning is a derivative work and is made available under the same license.*

Transforming Seabed Seismic



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Integrated Solution for OBN Data Processing

Software enables superior imaging for OBN data.

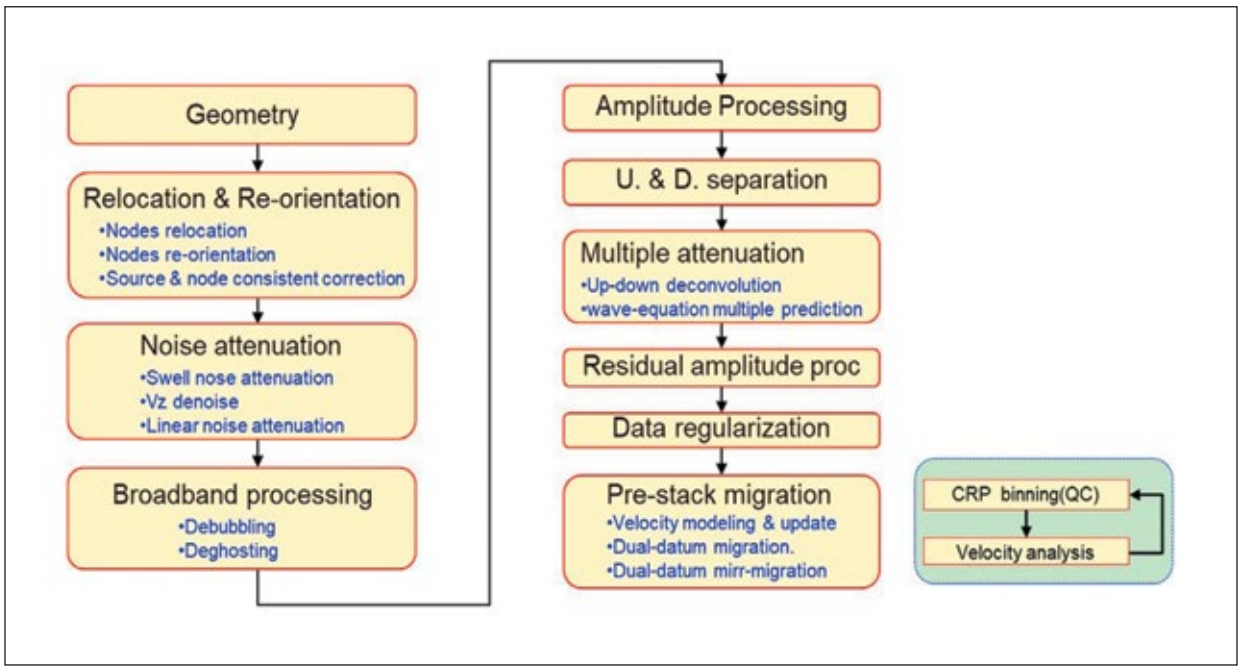
CONTRIBUTED BY BGP

In view of the characteristics and difficulties of OBN data processing, BGP has developed an integrated OBN data processing solution, including high-efficiency onboard processing, time domain processing and depth domain processing. The main technologies are as follows.

Data-driven three-component receiver re-orientation: Determines and corrects the orientation parameters of the receiver by performing polarization analysis on direct waves. This method is independent of the orientation parameters recorded in the field. Meanwhile it can be used to verify the field orientation.

Adaptive Vz noise attenuation: Uses the four-component adaptive matching technique to adaptively recover the signals of the X, Y and Z components into the component to which it belongs. This method can protect the effective signal of the Z component to the greatest extent while effectively suppressing the shear wave noise, so that P component and Z component can be matched better, and the subsequent wavefield separation is improved.

Common reflection point binning: The CMP stacking is no longer applicable because the shot and receiver are not at the same depth level for OBN acquisition. It is based on Snell's law to calculate the space-time variable trajectory of the reflection points, and the travel time is calculated by the non-hyperbolic travel time so that the direct processing of the OBN data can be realized, and the structure error existing in CMP stacking for deepwater OBN processing is solved.



BGP provides an integrated solution for OBN data processing. (Image courtesy of BGP)

Up and down wavefield successive separation: The method establishes the characteristic coefficient equation based on the energy criterion of the cross-correlation function between the up-going wavefield and the down-going wave field, and the optimal up- and down-going wavefield separation coefficient could be obtained iteratively.

Up-down deconvolution and wave-equation multiple prediction: The multiples associated with the bottom in the up-going and down-going wave can be respectively

See **SOLUTION** continued on page 13

Economics Matter: Beyond Dots in the Box

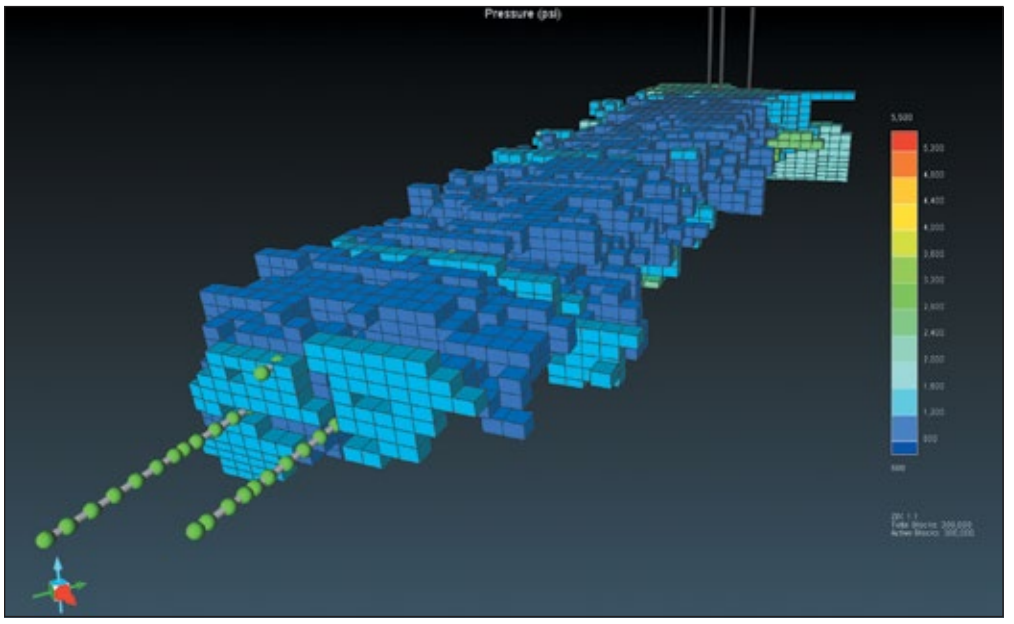
Microseismic-based model and data analytics platform maximize the ROI of the pad.

CONTRIBUTED BY MICROSEISMIC INC.

The last few years at MicroSeismic Inc. have been spent working to understand customers' challenges and to help them achieve their biggest goal—generating positive cash flow. MicroSeismic helps them increase drainage volume and drive costs down via well spacing, well configuration, effectiveness of the frac, treatment order and treatment design.

FracRx is the formalization of MicroSeismic's data analytics and synthesis platform by integrating multiphysics data to derive a prescriptive solution for improved well economics, maximized drainage volume, optimized completion and risk mitigation. This solution helps customers increase their net present value (NPV) and return on investment (ROI).

The example below shows how FracRx was applied to three wells drilled in a dry gas reservoir in the Appalachian Basin of the Geneso/Marcellus formations. The paramount objective of this project was to estimate the extent of the fracture network, evaluate the communication between wells, and examine the current state of well spacing. Understanding the volatility in gas price, MicroSeismic took the project one step further and performed an economic and sensitivity analysis on the well spacing and pattern to find the solution that would maximize the NPV of the pad.



A 3-D view of pressure distribution shows how the optimal well placement leads to effective drainage of the reservoir after 30 years of production. (Image courtesy of MicroSeismic Inc.)

Modeling production behavior

One of the major challenges in reservoir modeling in unconventional reservoirs is determining the dynamic drainage volume. MicroSeismic addressed this challenge through the application of a microseismic-based permeability model. The permeability model, derived from microseismic data, enabled the company to accurately calculate the evolution of drainage volume and to evaluate the communication between wells through time. Integrated with available well log, core and pressure-volume-temperature data, the reservoir model was calibrated to model gas production using three years' worth of production data. The production forecast was carried out to calculate the estimated ultimate recovery (EUR), which is a direct measure of the long-term success of the project. The extension of drainage volume far beyond the vicinity of the wells suggested that an increase in well spacing could benefit the production. While this may be true, the increase in well spacing could lower the production per acreage, leading to a loss in the overall economics of the project. Therefore, a comprehensive sensitivity analysis was performed to determine the impact of the well spacing on the production and economics of the pad. In addition to the current completion plan and after a thorough study of the drainage volume, a new completion pattern was proposed to improve the production of the pad and to lower the drainage zone overlap detected during the stimulation and production of the pad.

Economic approach to optimal well spacing

A sensitivity analysis conducted on the well spacing and pattern shows the significant impact of the completion design on the success and economics of the wells. The reservoir modeling shows that communication between wells declines with an increase in well spacing. However, it is capped to a certain limit where further increase does not impact the communication. Well spacing wider than 1,200 ft (366 m) for the original completion and 800 ft (244 m) for the proposed chevron pattern does not show communication between wells for this project. Although the overall production of the pad increases with wider well spacing, MicroSeismic did not recommend an increase in the distance between wells due to the growth in the size of undepleted zones. Pads with tighter well spacing consistently perform better compared to wider well spacing when the maximum production per acre and NPV per acre are targeted. The completion pattern and well spacing are not the sole factors in the success of the project; the analysis shows that the gas price drastically impacts the economics of the project. Using these

See **ECONOMICS** continued on page 13

Salt-related Full-waveform Inversion

Are we there yet?

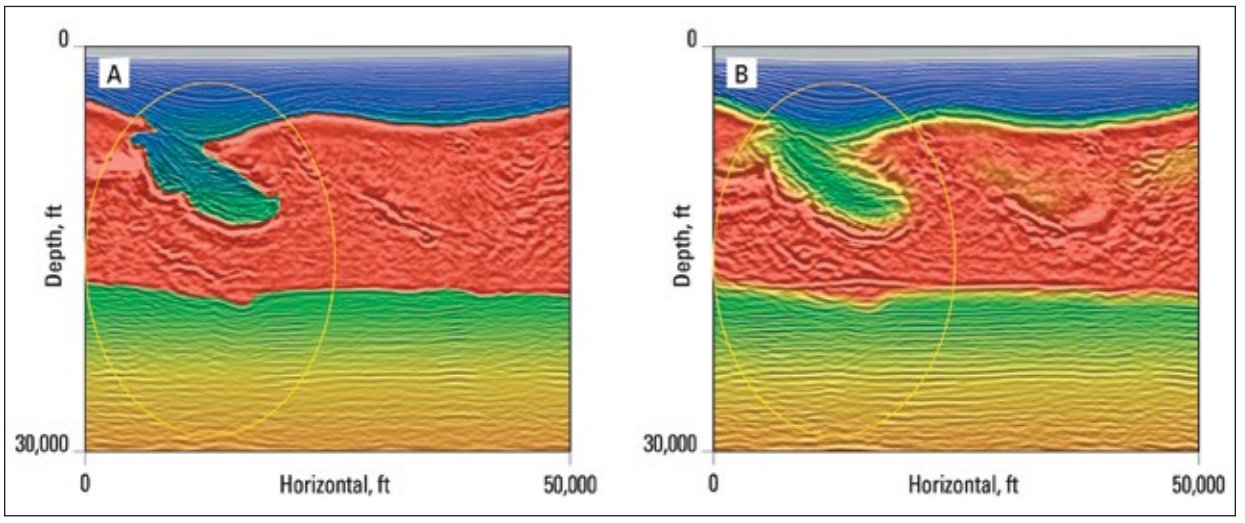
CONTRIBUTED BY WESTERNGECO, SCHLUMBERGER

Salt-related full-waveform inversion (FWI) is being increasingly used due to new acquisition schemes like ocean-bottom nodes with long offsets up to and beyond 80,000 ft (24,384 m) and with low frequencies down to and even below 2 Hz. Past attempts to modify and reshape salt used existing streamer data due to its lower cost. Early attempts with FWI assumed smooth salt boundaries, but recently, due to mis-ties at wells and difficulty removing smooth salt boundaries from the model, the industry is considering reverting to sharp salt representation.

One of the most difficult parts of subsalt imaging is building the correct salt geometry and defining the salt velocity. Salt geometry building becomes more complex if there are several salt overhangs that must be incorporated into the model. FWI is considered one of the promising data-driven techniques to build velocity models by iteratively minimizing the difference between observed and predicted data. Successful examples using FWI to update shallow sediments, gas pockets and mud volcanoes have been reported; however, success using FWI to update salt structures remains very challenging.

Early FWI implementations were successful on simple geology, mostly addressing low-velocity gas pockets or high-velocity injectites mainly in the shallow part of the velocity model using the diving waves. Few attempts were dedicated toward salt-related FWI due to salt geometry complexity, lack of ultralow frequencies and short offsets; consequently, these efforts showed limited success.

Real data examples using smooth salt bodies in the starting model originating from legacy classical model building allowed FWI to change the model in conjunction with the shape of the salt. Most of the examples had success on shallow salt bodies that can be modified by relatively short-offset (5-5.6 mile or 8-9 km) streamer acquisition. One of the problems of this approach is that it leaves a salt halo footprint in the model. To make this procedure easier for users, the sharp salt workflow was introduced as a mask and inserted in the sedimentary model during forward modeling. This flow is convenient for users, but requires good knowledge of the salt. It works well freezing the top of salt to update the suprasalt sediments only.



(A): Sharp salt via interpretation and its image; (B): Changed smooth salt with FWI update and its image. (Image courtesy of Schlumberger)

Therefore, we ask, must we provide sharp salt or is the smooth salt good enough for imaging, pore-pressure prediction and other beyond-imaging products required to evaluate prospects? Salt halo removal or, in other words, resharpening the salt is a difficult proposition because the halo around the salt must be replaced by the correct sediment velocity all around the body without degrading the image and changing gather kinematics. Approaches to maintain the salt sharpness through the level-set or the hinge constraint FWI have not proved robust for real data exercises yet.

Another rather expensive proposition is to run FWI to high frequencies to automatically remove the salt halo from the model.

The recent interest in updating models including salt using FWI owes its origin to optimally designed seismic acquisition, namely long-offset, broadband and ocean-bottom node surveys. However, questions still remain regarding smooth or sharp salt model decisions and why acoustic modeling may be a close-enough approximation in a highly elastic medium, especially with ultralong offsets. While the first convincing applications of 3-D FWI were performed with stationary ocean-bottom cable systems, other such surveys are currently being acquired with towed streamers, especially for exploration purposes.

Further details are available in the 2019 SEG technical paper titled "Is the Salt-related Full-waveform Inversion Sorted Out?" This paper will be presented on Tuesday in Room 302B at 8:30 a.m. as part of technical session FWI 2: Salt Model Updating. To learn more about salt-related FWI, please visit WesternGeco booth 2438. ■

Building Trap Scenarios and Analyzing Their Uncertainty

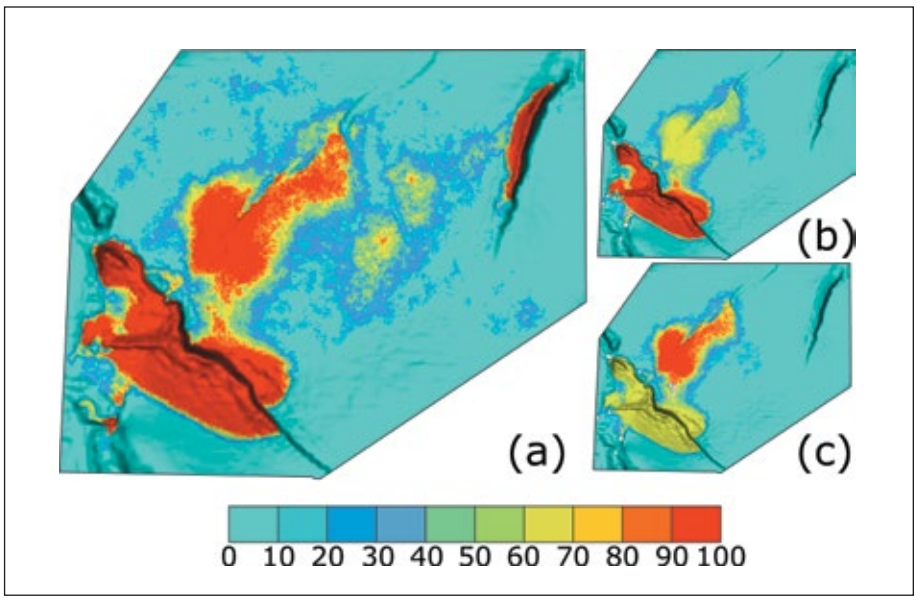
A new workflow from depth conversion and calibration to trap and volume analysis considers several sources of uncertainty.

BY HÉLÈNE BINET, GEOVARIANCES

Seismic acquisition is performed with more or less accuracy depending on location and investment made. These data are processed through a series of algorithms such as filtering, stacking or migration. A geophysicist, often subjectively, interprets the data in their natural time unit. And then, using one of the multiple possible approaches, depth converts that interpretation to a hopefully coherent and structurally reasonable depth model. And now the questions arise: where should we drill, and how much of the resource can we expect? Conceptual modeling of reservoirs is part of the decision-making process, and trap analysis is an important step in reaching this objective. This is typically performed over depth horizons, which are a result of time-to-depth conversion operations. Not only does this operation carry uncertainty but also depends on other elements, such as faults.

Geovariances developed a workflow to achieve a proper uncertainty assessment in trap analysis. First, the company applied a Universal Kriging-based approach to generate stochastic realizations of the same depth horizon, exploring the uncertainty space. It enables an assessment of the different structural possibilities for the same trap. The advantage of the method is that it considers both hard data (well depth markers) and soft data (time horizons). Then, another processing step adapts the horizons to different lateral positions of faults. Finally, using a novel trap analysis algorithm, Geovariances analyzed the consequences of different sources of uncertainty, including time or velocity uncertainties.

So how to use all those results? It's not necessary to take all the achievements for granted or treatable. It is to prove or disprove the meaningfully different scenarios obtained in a very significant percentage of the realizations. A relevant observation of the different uncertainty maps coupled with the study of probability curves must be made and can reduce to two or three relevant scenarios. In the case study, the results show clearly different, but plausible, structural scenarios, whose impact on exploration operations is likely to be significant. Using the documented trap analysis workflow can lead to significant changes in reservoir volumes in adding lateral fault position uncertainty. In an extreme case this could lead to new reservoir areas.



Case study: (a) Plot of the probability map of all reservoir areas. (b) Plot of the probability map only for the reservoir on the left. (c) Plot of the probability map for the reservoir near the center. Notice how two major reservoir areas are clearly visible. Less obvious is the uncertainty in the link between the two reservoirs. There is one obvious, high probability link to the right. The other, less likely but still feasible, is to the left. (Image courtesy of Geovariances)

To learn more about this project attend "The Emergence of Edge Scenarios in Uncertainty Studies for Reservoir Trap Analysis," Geovariances' poster presentation, from 10:10 a.m. to 10:35 a.m. on Tuesday, Sept. 17, Poster Station 5. Visit Geovariances at booth 1045. ■

Large-scale Deployment of Autonomous OBN Technology

Robotic technology delivers significant performance improvements in seismic and beyond.

CONTRIBUTED BY SEABED GEOSOLUTIONS AND SAUDI ARAMCO

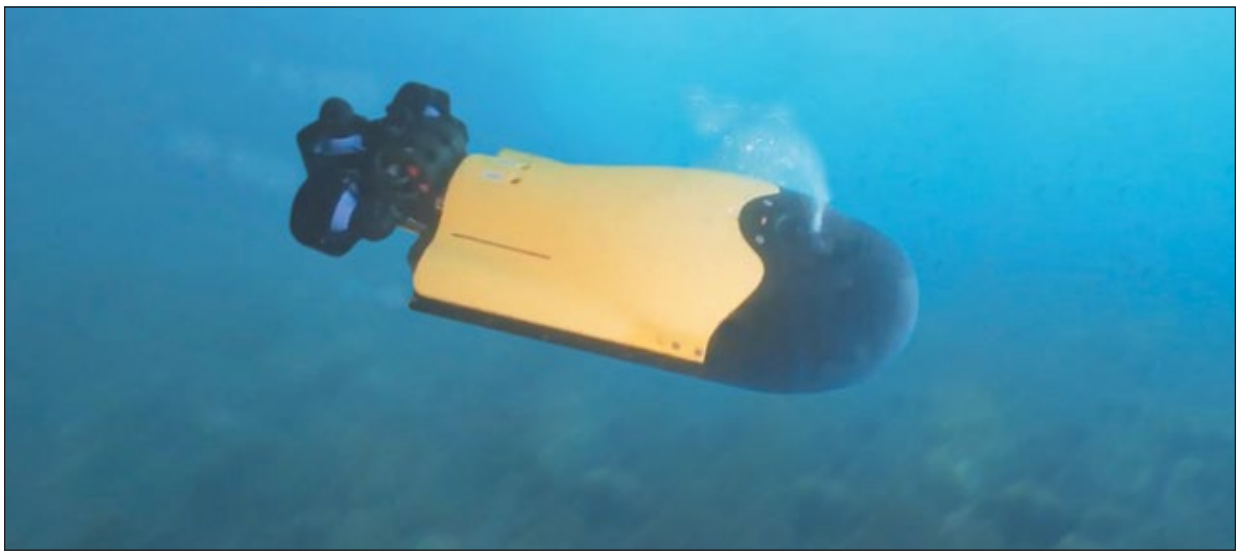
The adoption of ocean-bottom node (OBN) technology has been driven by seismic contractors' efforts to reduce operational cost through investment in automating node deployment and recovery technology in complex offshore seismic operations. In recent years, OBN has moved from a niche solution for very challenging imaging and monitoring objectives to a more prevalent solution, making up a larger proportion of the seismic market.

The demand for an OBN deployment and recovery solution that will lower costs and reduce HSE exposure without impacting seismic data quality led to a joint program between Saudi Aramco and Seabed Geosolutions in 2013. The program, named SpiceRack, involved integrating the ocean-bottom seismic node with the advances in "flying" AUV technology. Each SpiceRack node is an autonomous seismic recording unit that propels and navigates itself to and from the pre-plot location where it records data. This solution is now very close to showcasing the first seismic data image generated from an autonomous node.

The existing deployment model requires a large mother vessel operating multiple ROVs, which are cabled to the vessel. Large teams of ROV operators onboard the mother vessel steer the ROVs to the correct location to deploy or recover each node independently. While AUVs are heavily used by many other marine industries including Maritime Safety and Security, Surveillance of the Protected Marine Areas, and Harbors' Protection, to name a few, the AUV seismic node has very specific challenges. These include management of ultra-large fleets of vehicles requiring high precision positioning and operating interdependently where data transmissions in liquid are limited as opposed to air domains. AUVs do not benefit, as do flying drones, of long-range, high-frequency radio transmissions and, of course, satellite positioning solutions. The physics of acoustic underwater transmission cannot be breached and dictates the very particular operational models required to ensure successful missions deploying many AUVs.

Saudi Aramco and Seabed Geosolutions have invested heavily to overcome these challenges, capitalizing on industry and non-industry research. Several tests using SpiceRack units have already been performed for validation of the navigation and propulsion systems, understanding the deployment accuracy and confirmation of the coupling consistency. A small seismic image was generated from a test of 20 prototype units. Following the success of those qualification steps, 200 first-generation SpiceRack nodes will be utilized in a pilot test to acquire a subsurface image. Once survey parameters are loaded, the nodes will be launched at a high rate of speed through a ramp and propel themselves to the pre-plot location, forming an array of receivers on the seafloor. Then the AUV node will act like any existing OBN, continuously recording multicomponent measurements. After completion of the shooting plan, the SpiceRack nodes will answer a signal to raise from the sea floor and head to a recovery basket where they will be recovered for data download and battery charging. Pilot test operations will only require a team of 10 on a 131-ft (40-m) support work boat.

To address the market segment created by robotic technology, there will be crews operating thousands of AUV nodes in the future. This unpreceded number of AUVs will bring down production costs and make this technological development accessible to an even larger number of markets and applications. What Saudi Aramco and Seabed Geosolutions are offering is not only a step-change in seismic, but a new perspective to the utilization of AUVs to monitor and scan the oceans, the largest unexplored surface on the earth. ■



SpiceRack OBN "flies" back to the recovery basket. (Image courtesy of Seabed Geosolutions)

Visit the SEG Book Mart

Be sure to check out the SEG Book Mart in the main lobby of the convention center. Visit with SEG authors, have your new books signed, check out the latest SEG merchandise and shop the many titles on sale.

Advancing Exploration, Production through OBN Technology

Acquisition completed on largest ultra-long offset deepwater OBN survey in the U.S. GoM.

CONTRIBUTED BY TGS

Ocean-bottom node (OBN) acquisitions have been in the industry since the early 1990s, beginning in the North Sea. Growing in popularity in the 2000s, this marine technology played a significant role in seismic observation focused on small production projects. OBN acquisition provides much cleaner seismic signal than conventional narrow-azimuth streamer surveys with focus on 4-D with unmatched repeatability. By the early 2010s, OBN technology became more reliable, flexible and affordable to take on larger scale acquisitions. In 2019, acquisition was completed on the industry's first and largest ultra-long offset deepwater multiclient OBN survey (the Amendment) in the U.S. Gulf of Mexico (GoM) reaching maximum depths of 2,070 m. The Amendment survey covers 118 OCS blocks utilizing offsets out to 40,000 m.

Deployment of nodes began in early May with the firing of 1.6 million shots, and recovery of the nodes was completed in August 2019. The crew consisted of two ROVs laying out nodes in a 1-km by 1-km grid and three source vessels to record the active node patch. This four-month survey was conducted without any HSE recordable incidents.

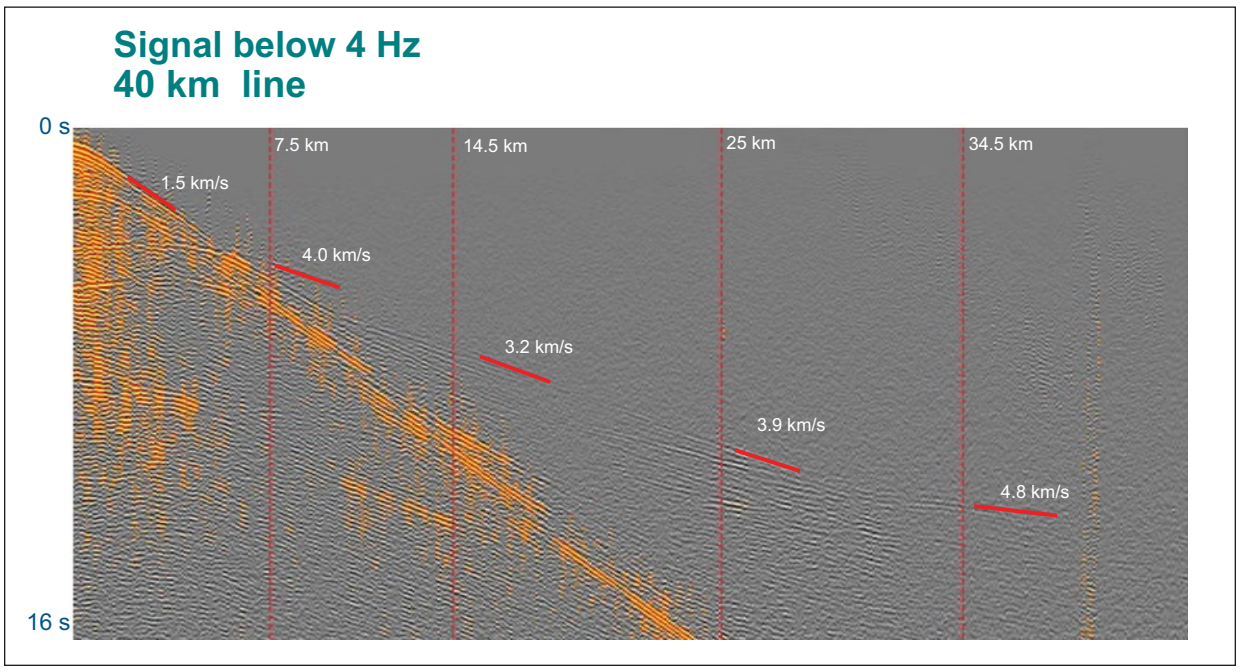
Simultaneous operations were recognized as a challenge during the mobilization hazard identification review. The crew went around 14 fixed structures and three "slow-moving" assets (wave gliders). For each fixed structure the communication between the offshore installation manager and the crew was essential for the close passes; on average eight close passes were acquired per fixed structure, so the crew executed over 110 close passes. As for the slow-moving assets, the crew was communicating with the wave glider coordinator out of California to prevent collision paths.

The Amendment survey was designed with a receiver carpet of 2,700 sq km and a 50-m by 100-m shot carpet of 8,000 sq km. The nominal offset is 40 km and the max-min offset range is 20 km in the shot halo. This full azimuth dense shot project was designed to deliver a dataset that is suitable for both full-waveform inversion (FWI) velocity and seismic imaging updates. The source volume was a 501 cu in. air gun used to record signal down to 1.5 Hz at 20 km offset. In production shots the larger source was used for stability reasons and to acquire low frequency signal below 3 Hz to give FWI more reliable signal for velocity model building.

One of the primary objectives for this large deepwater exploration scale survey is to improve illumination of targets, especially in subsalt basins. This is obtained by a very dense and large offset shot grid that allows ray paths to travel, reflect and refract deeper with the salt flanks interfaces. With the improved subsalt refractions diving waves easily reach to the Louann Salt, the predominant "mother" salt in deepwater GoM.

We expect significant uplift in data quality over existing data. The uplift will come from the unprecedented sampling of azimuths and ultralong offsets. This will be a challenge for the preprocessing in terms of deghosting, demultiple and other pre-imaging steps. This is a step change in the application of refraction FWI to improve velocity model building and we are expecting the increased coverage of the subsurface will result in subsalt events for reflection FWI and multi-arrival tomography.

To find out more about OBN offerings from TGS, visit booth 2138. ■



The image is a shot line from a single node; the data have been filtered to max 4 Hz. The data show refracted signals up to 40 km. (Image courtesy of TGS)

The Data Challenge

Geomechanics approach goes a long way toward helping safe and successful operations.

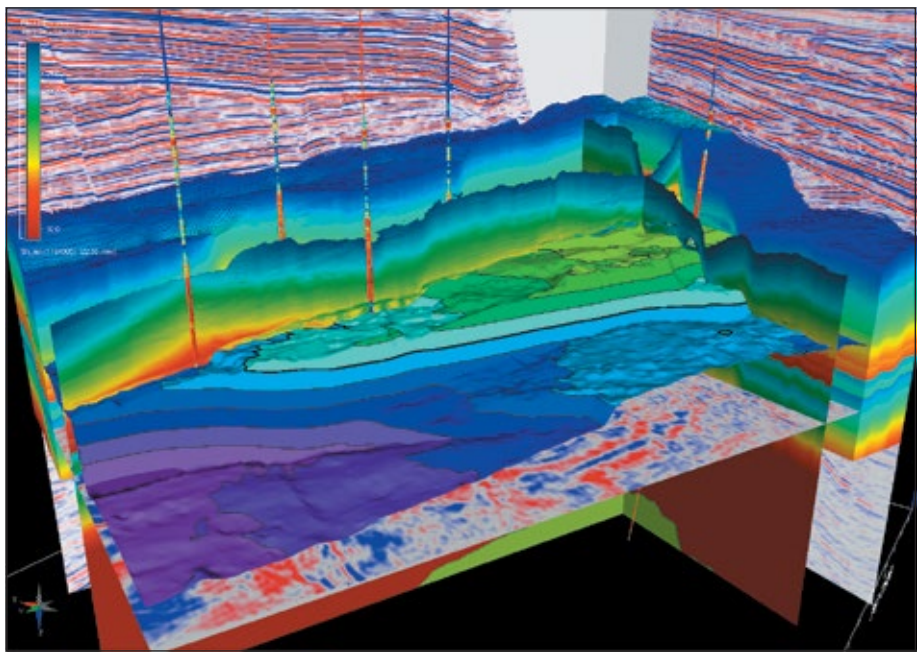
CONTRIBUTED BY IKON SCIENCE

Insight to the geomechanical properties of a reservoir and its overburden are critical to risk assessment, whether it's optimizing well designs and trajectories, wellbore stability during drilling, well completion programs, or reservoir monitoring and performance during production. To effectively propagate and communicate risk within full 1-D to 4-D workflows for geology, geophysics and drilling, an integrated multiscale solution that combines all data types is required.

Ikon Science provides this with the RokDoc Geomechanics add-on available in RokDoc 6.7.0, released at SEG 2019. It provides an integrated geomechanical risk modeling solution of cross-disciplinary workflows, leveraging the interaction between geopressure, QI rock properties and drilling. Users can intelligently extrapolate geomechanical properties and robust subsurface models. RokDoc's single-platform workflow allows all data to be captured and multiple models to be tested quickly in order to effectively evaluate any uncertainty. This facilitates the clear and consistent communication of risk.

"The ability to calibrate 1-D to 3-D models and perform multidisciplinary analyses in one place accelerates the process of reservoir characterization with geomechanical volumes. Before this release, we were limited to providing the information purely as a service, using highly trained experts and complicated python scripts—now, the tools are readily available and relatively easy to learn," said Mark Bashforth, Ikon Science CEO.

A significant new feature for this version release is the addition of the 3D Analytic Geomechanics calculators. This new functionality, which comes as part of the Geomechanics add-on to the pore pressure prediction module, allows users to combine 1-D geomechanical models with 3-D elastic property models to create 3-D representations of the *in situ* stress state. Once the model is defined, users can readily extract well profiles based on conceptual target locations or planned trajectories to investigate drilling parameters such as collapse curve pressure, mudweight windows and rock strength, which can all be used to refine and improve drilling target selection and well design.



The image shows 2-D/3-D analytical geomechanical property models in RokDoc. (Image courtesy of Ikon Science)

"We use the outputs to direct well placement for optimizing production and well design. The end-use for engineers includes inputs for frac-modeling, variations in hydraulic fracture gradients and much, much more," said Alexander Edwards, global portfolio manager, Wells.

See **CHALLENGE** continued on page 13

SOLUTION
(continued from page 8)

suppressed by the combined up-going and down-going wavefield deconvolution and the wave-equation multiple prediction.

Dual datum PSTM: In view of the problem of big elevation differences between shots and the receivers in deepwater OBN acquisition, this method deals with the asymmetry by calculating the travel time at different datum and simultaneously performing the conversion of velocity and imaging time of different datum.

Mirror migration: It uses first order receiver-side ghost to obtain better images, which gives better illumination than that by up-going primary wavefields, especially for the shallow layers, and can effectively solve the imaging error for the seabed and subsurface caused by the sparse distribution of the receiver in the OBN acquisition.

BGP's integrated solution for OBN data processing has been applied in different areas. ■

ECONOMICS
(continued from page 9)

wells as an example of optimum well spacing and pattern demonstrates that when the price of gas increases from $2/Mcf to $3/Mcf, the payback period of the initial investment drops from one year to only six months, which could be a major factor in evaluating the success of the project.

Maximizing NPV in real time

MicroSeismic has introduced a sophisticated approach for completion design aiming to improve frac efficiency and to achieve large stimulated volumes with the expectation of achieving increased EUR and NPV. Yet, no matter how sophisticated the completion design is, it simply cannot accurately predict frac hits, which can significantly impact how efficiently wells are getting completed. The only way to minimize frac hits, ergo higher frac efficiency, is by real-time monitoring of fracture propagation and their corresponding microseismic events, which allows for a prescribed solution that helps operators achieve the highest possible NPV on individual wells and ROI on the entire pad.

MicroSeismic Inc. provides an advanced economic solution to attain profitability through the integration and evaluation of all available data. Visit booth 3634 on Tuesday, Sept. 17, at noon for the Lunch and Learn, "How FracRx Helps Increase ROI," presented by Peter Duncan, CEO of MicroSeismic Inc. ■

CHALLENGE
(continued from page 12)

When combined with the 4D Reservoir Monitoring add-on, the 3-D geomechanical models become inherently 4-D, allowing asset teams to explore the impact of production-related changes on existing and future infill locations such as borehole stability and overall integrity. Geomechanical attributes that are sensitive to production can then be clearly tied to 4-D seismic responses, improving confidence in this complex interpretation task.

In addition to Geomechanics workflows, RokDoc 6.7.0 continues to see focus on usability, with new features around well data loading providing significant ergonomic improvements. In the Pressure Prediction Module, updates to the Pressure Translation Tool now allow users to translate pressure data to new offset or prospect locations across multiple wells simultaneously, reducing the need for repetitive tasks.

Ikon Science will also introduce direct two-way connectivity from iPoint to RokDoc 6.7.0 and the Petrel platform through the Petrel adaptor, allowing users to easily transfer all of their wellbore-centric data between the three platforms, thus providing an innovative solution for capturing, standardizing, and delivering important interpretive results to and between geoscientists, laboratory technicians and engineers across their organization.

At SEG this year, the Ikon team will be delivering six oral conference presentations as well as chairing several technical sessions. These presentations, along with a number of additional technical, solution-focused booth talks from both Ikon and industry guest speakers should make for a very exciting and informative convention. ■

Future SEG Annual Meetings

2020
11-16 October 2020
George R. Brown Convention Center
Houston, Texas USA

2021
26 September–1 October 2021
Colorado Convention Center
Denver, Colorado USA

2022
11-16 September 2022
Kay Bailey Hutchison Convention Center
Dallas, Texas USA

2023
5-10 November 2023
Ernest N. Morial Convention Center
New Orleans, Louisiana USA

RESERVOIR
(continued from page 4)

reservoir attributes from seismic attributes, such as prestack inversion results and amplitude, frequency and phase volumes. Two decades on, "deep learning" technology has now been added to Emerge to improve reservoir property prediction using deep feed-forward neural networks, which is producing an uplift in results compared to the previous generation of techniques.

As well as offering the latest technology in its new releases, CGG GeoSoftware is migrating its software to the cloud to provide greater opportunity for collaboration. The cloud offers more than just data storage—cloud computing provides scalable and flexible solutions to compute-intensive reservoir characterization workflows and very large projects. Through technical collaboration with Microsoft, the latest GeoSoftware releases run seamlessly in the Microsoft Azure Cloud Environment. Other major cloud platforms will follow soon.

To get the full picture, join CGG at 3:30 p.m. Tuesday at booth 3347 for a presentation on machine learning with Brian Russell, then stay for a Happy Hour discussion on GeoSoftware's roadmap to the cloud and a live software demonstration in Azure. ■

High-Resolution Seismic Imaging in Shale Plays

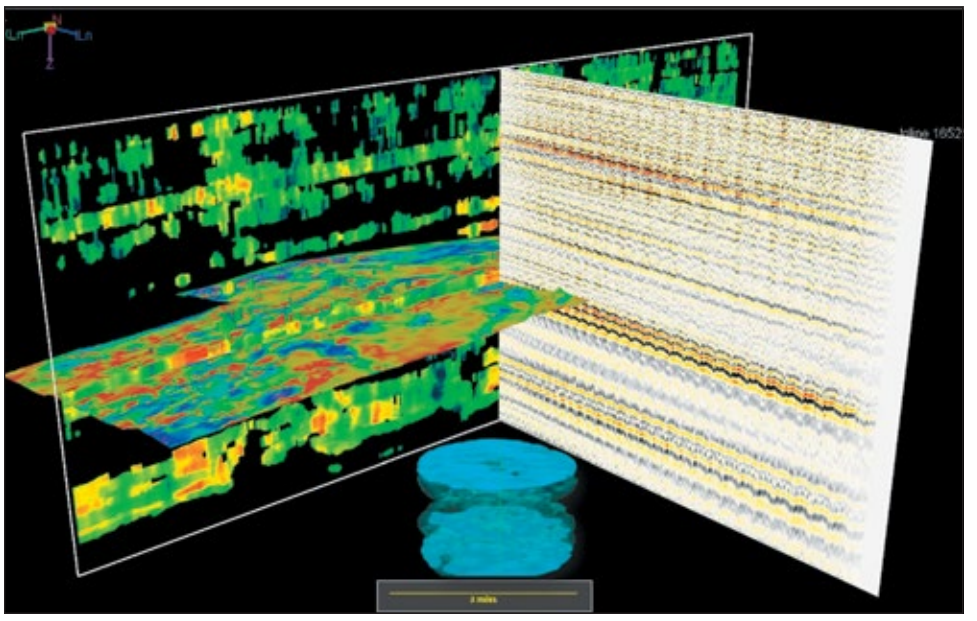
Two methods boost confidence in prospecting and field development decisions.

CONTRIBUTED BY EMERSON

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

See **IMAGING** continued on page 15

PROSPERITY
(continued from page 1)

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
(continued from page 14)

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
(continued from page 1)

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.

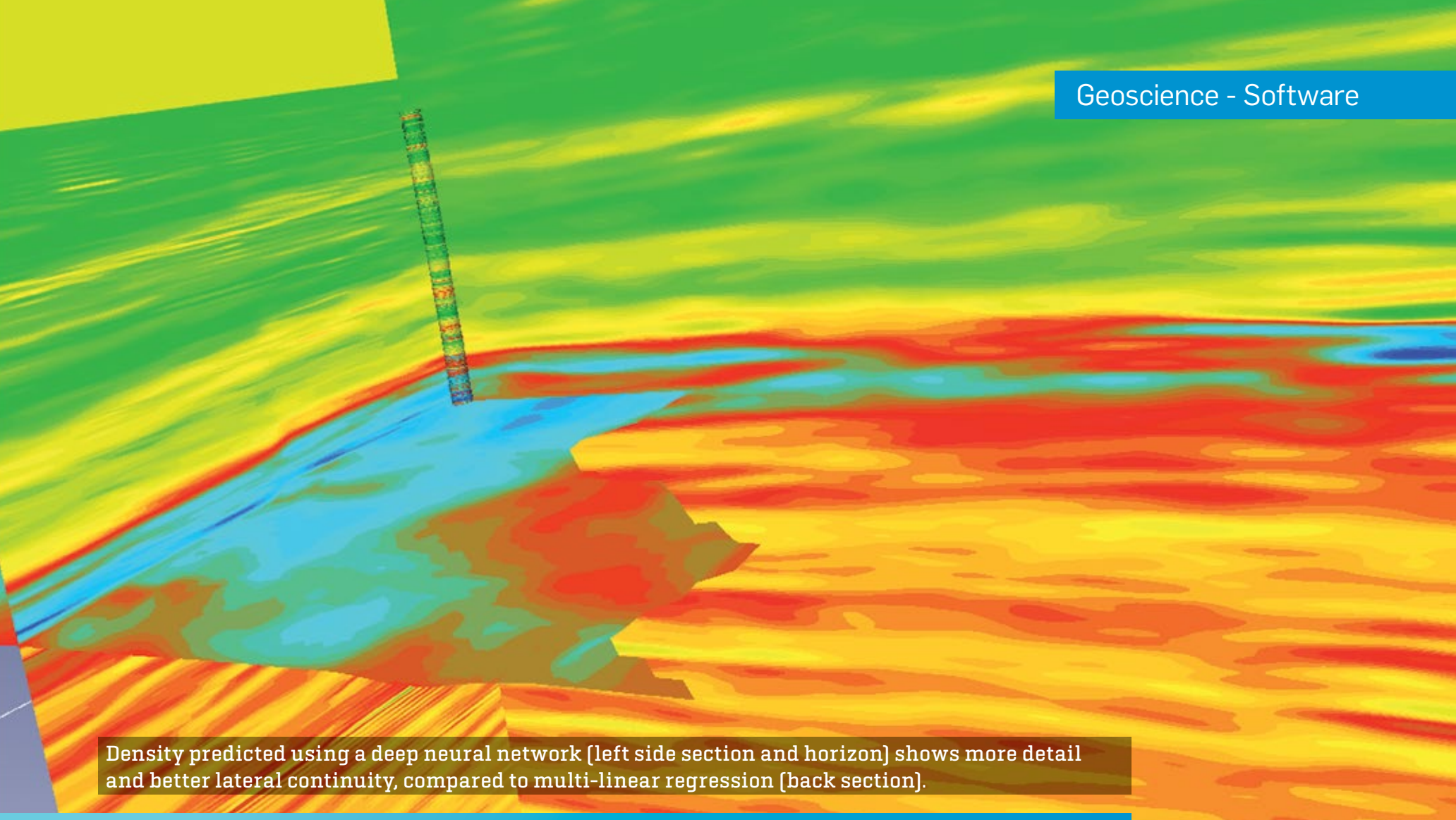
The third proposal of the day—to properly define the term "Voting Members" within the SEG Bylaws—was the quickest to pass and garnered no discussion before the council voted overwhelmingly in its favor. The amended bylaws would capitalize the term "Voting Members" throughout, and a definition would clearly 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. ■



Density predicted using a deep neural network (left side section and horizon) shows more detail and better lateral continuity, compared to multi-linear regression (back section).

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