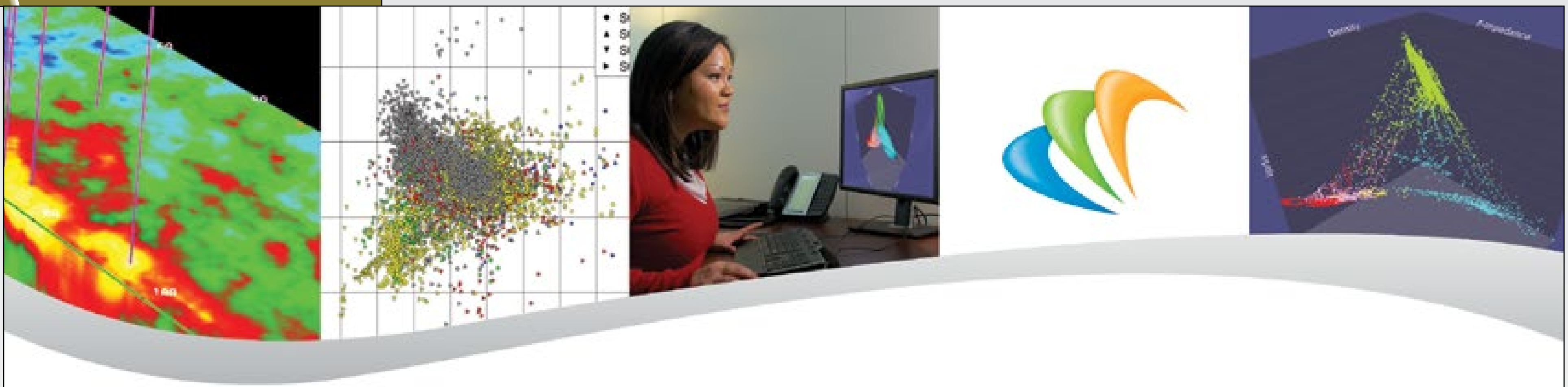
AAPG EXPLORER

OCTOBER 2015

Under Pressure

The geophysical industry finds new reserves of innovation.

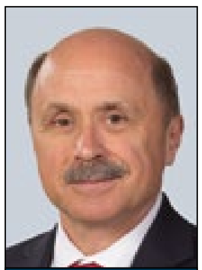


PRESIDENT'S COLUMN

Publication Model Challenged by Digital Access

BY MIKE SWEET, AAPG ELECTED EDITOR

(From AAPG President John Hogg: Once again I'm offering my column space to a member of the AAPG Executive Committee for a report on activities and trends in their respective area. This month we turn the spotlight on AAPG publications, with a message from our Elected Editor, Mike Sweet.)



SWEET

The bottom line: In the world of scientific publication, our model of selling papers to non-members is threatened by the Open Access movement.

Scientific publishing is undergoing major changes driven by the shift to digital publication – and the digital revolution will continue to change the way that AAPG disseminates our science.

A look at the BULLETIN circa 2000 would show a scientific journal published in a form and on a media (paper) that was essentially identical to the first scientific journals of the mid-17th century. Move forward 15 years and the BULLETIN, for most of our members, is distributed and accessed online.

Over the next three years we plan to upgrade this delivery system to use an app, which will allow subscribers to read the BULLETIN on their smartphones or tablets. In a digital format we have the opportunity to publish more elaborate color images at no cost to the author – and in the future we can include video and animation.

While digital delivery opens the door to more interactive presentations of geologic data, it also comes with new challenges. As with other media (books, video and music) free sharing of content becomes easy, and there is constant pressure from the consumers to receive content for free or at a nominal cost.

Of course, a significant portion of the cost of publication of any journal is related to the pre-print editing and layout – and selling papers to non-subscribers is a significant source of revenue for AAPG publications, which helps to offset losses in other areas (such as books; more on that later).

The bottom line: In the world of scientific publication, our model of selling papers to non-members is threatened by the Open Access movement.

This publication model – where the authors pay publication costs and the publishers give digital contests away for free – started in part as a reaction to the large profits made by for-profit publishers like Springer and Elsevier from selling subscription to journals in biomedical fields, where much of the research is funded by public money.

This is aggravated more by reduced library budgets.

While we have enacted an Open Access policy that is compliant with U.K. law, most of our researchers are funded with industry money, and few authors have used this option to date. GSA is going completely Open Access with its journals, at significant cost to their society.

It remains to be seen if the market will force other journals, including the BULLETIN, down this route.

* * *

While the BULLETIN has benefited from digital technology and is reaching an ever-larger audience, books sales were dropping even before the current oil price crash.

While we have published over 200 books, CDs and map titles, most only sell 200-500 copies – and our total sales are dominated by a few very popular textbooks. For example, Basic Well Log Analysis has sold over 12,000 copies in the last 10 years alone.

The technology exists to do small print runs and print additional books on demand. Undoubtedly, more of our books in the future will come out digitally or use on-demand printing, which will allow us to break even on smaller print runs.

We also are starting to sell papers from our books digitally through Geoscience World. However, given current trends, it's an open question if there will continue to be a market for the Memoir series in the future.

AAPG President John Hogg (center) and AAPG Executive Director David Curtiss (right) speak with a group of YPs at the recent International Conference and Exhibition (ICE) in Melbourne, Australia. A full report on ICE will be included in the November EXPLORER.

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REGULAR DEPARTMENTS

Scan this for the mobile version of the current web Explorer.

Photo courtesy of PGS

ON THE COVER:

Castle Geyser at Yellowstone National Park in Wyoming. Geophysicists recently discovered an enormous reservoir of magma beneath Yellowstone, which is somewhat symbolic of the enormous reserves of invention and innovation within the geophysical industry. For the story on Yellowstone, see page 16. For the stories on geophysical innovation, look throughout. Photo courtesy of Wikipedia user "Flicka."

Left: PGS's Ramform Atlas shoots offshore 3-D seismic using towed streamers. For an overview on the current state of the geophysical industry, see page 14.

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It's the End of YPs as We Know It and We Feel Fine

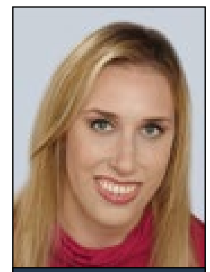
By JONATHAN ALLEN and MEREDITH FABER, AAPG Young Professionals Committee Co-Chairs

The summer may be winding down, but things are just heating up for the AAPG Young Professionals (YPs).

We had an awesome time at ACE in Denver this past June with impressive turnouts at both the YP Meet and Greet and the YP networking reception in downtown Denver. Both events were graciously sponsored by Noble Energy and we thank them for their ongoing support of YP initiatives! Feedback from attendees at both events was overwhelmingly positive.

ALLEN

> "Now, all members interested in the YP mission and its initiatives have a venue in which to participate."



FABER

The biggest YP-related news of the meeting came from the House of Delegates. The HoD approved an amendment to the AAPG Bylaws that formally adopted the creation of special interest groups (SIGs) and technical interest groups (TIGs).

The First SIG

The Young Professionals are very excited to share that the Executive Committee approved the YPs as the first AAPG SIG this August. We are looking forward to exploring this new avenue the association has recently created. There is now a dedicated space within the Association from which to progress the mission and vision of the large and growing population of young professional AAPG Members.

The current Young Professionals Membership Committee will comprise the governing body of the new YP SIG with representatives from each Section and Region. The goals of the YP SIG will also remain the same as the currently operating Young Professionals Membership Committee.

The YP SIG will:

- Foster a challenging and successful career in the energy industry for recent graduates and early-career earth scientists.
- Build an understanding of the value of a lasting relationship between AAPG and young professional members.
- Encourage earth scientists to progress to full Member status.

The YP SIG will continue to provide the services that have been established by the YP Committee, including the YP Meet and Greet (held at ACE, ICE and Section/Region meetings), field trips, short courses, networking events and community outreach/volunteer events.

Benefits of Being a SIG

The value of the YP SIG is the ability to have a defined population of AAPG members interested in the activities of young professionals.

One of the major difficulties the YPs have had in recent years has been the inability to adequately identify YPs within the current membership structure. In order to reach what we felt was our targeted demographic, we have been defining YPs as "members under the age of 39." This is the group who receives all of the YP-oriented communication from AAPG.

Of course, it's reasonable to assume that some members receiving these communications do not define themselves as YP's and are not interested in the YP's.

Additionally, we are missing people who might be very interested in the YPs but are excluded based on our defined age limit.

Now, all members interested in the YP mission and its initiatives have a venue in which to participate: the YP SIG.

The YPs now have the ability to better target our audience, provide focused communication and have a pool of interested individuals to call upon as volunteers for various positions within AAPG and other associated Sectional/Regional groups: the members of the YP SIG.

Any member of the Association can become part of the YP SIG and benefit from services and programs we provide. We hope all who are interested will join the first SIG of AAPG and help our Association grow!

Be on the lookout for communication on how to join the YP SIG coming soon.

Mid-Continent Section meeting

Dispelling Myths About Seismicity

By DAVID BROWN, EXPLORER Correspondent

A recently published study of Oklahoma earthquake activity contradicts some popular beliefs about man-made seismic events.

The paper, authored by AAPG members F. Rall Walsh III and award-winning geoscientist Mark Zoback, appeared in June in "Science Advances," an open-access journal published by the American Association for the Advancement of Science.

Walsh is a fifth-year doctoral student at Stanford University. Zoback is professor of geophysics in Stanford's School of Earth, Energy and Environmental Science, and the 2015 recipient of AAPG's Robert R. Berg Outstanding Research Award.

Walsh will discuss their study in the presentation "Oklahoma's Recent Earthquakes and Saltwater Disposal" at the AAPG Mid-Continent Section Meeting, Oct. 4-6 in Tulsa.

Their research findings counter some widely held beliefs about Oklahoma's recent history of quakes.

Belief: Earthquakes originate at such great depth, they can't be caused by wastewater injection.

Finding: Saltwater disposal in Oklahoma, primarily injection into the Arbuckle Group, increases pore pressure, spreads away from injection wells over time and eventually triggers slip on critically stressed faults in


WALSH

> "As soon as we plotted the right data, (the connection between injection wells and earthquakes) jumped out at us."

basement.

"Faults that are mechanically active today are hydrologically conductive," Walsh noted.

According to the study, there's no doubt that wastewater from oil and gas activities is directly tied to Oklahoma's upsurge in earthquakes.

Belief: Oklahoma's induced earthquakes are mainly caused by the results of hydraulic fracturing.

Finding: Flow-back water from hydrofracturing contributes only a fraction of Oklahoma's injected wastewater. Almost all of the injected water in the earthquake study areas was produced water.

This is a relatively new idea – that the great majority of injected saline water in Oklahoma is produced water.

Belief: The small amount of energy used in hydraulic fracturing and other completion and production operations can't account for the huge amount of energy released by an earthquake.

Finding: Walsh and Zoback make it clear that increased pore pressure is simply a trigger for the release of already-existing forces.

"In the context of induced seismicity, the largest earthquake that might be triggered is determined by pre-existing geologic conditions, not the magnitude of the perturbation of pore pressure," they wrote.

Belief: Induced earthquakes can be mitigated or stopped by reducing injected volumes in the nearby injection well or wells.

Finding: "It is likely that even if injection from many wells were to stop immediately, seismicity would continue as pressure continues to spread out from past injection," Walsh and Zoback wrote.

Oklahoma has a very large number of wastewater injection wells, often closely clustered. Because increased pore pressure spreads away from injection wells over time, it can be difficult to determine which well or wells have triggered events. The effects could be cumulative.

"One of the features of Oklahoma is that often we can't identify the 'one well.' You might have 100 or 200 wells within an hour or an hour-and-a-half's drive of each other," Walsh said.

Where the Action Is

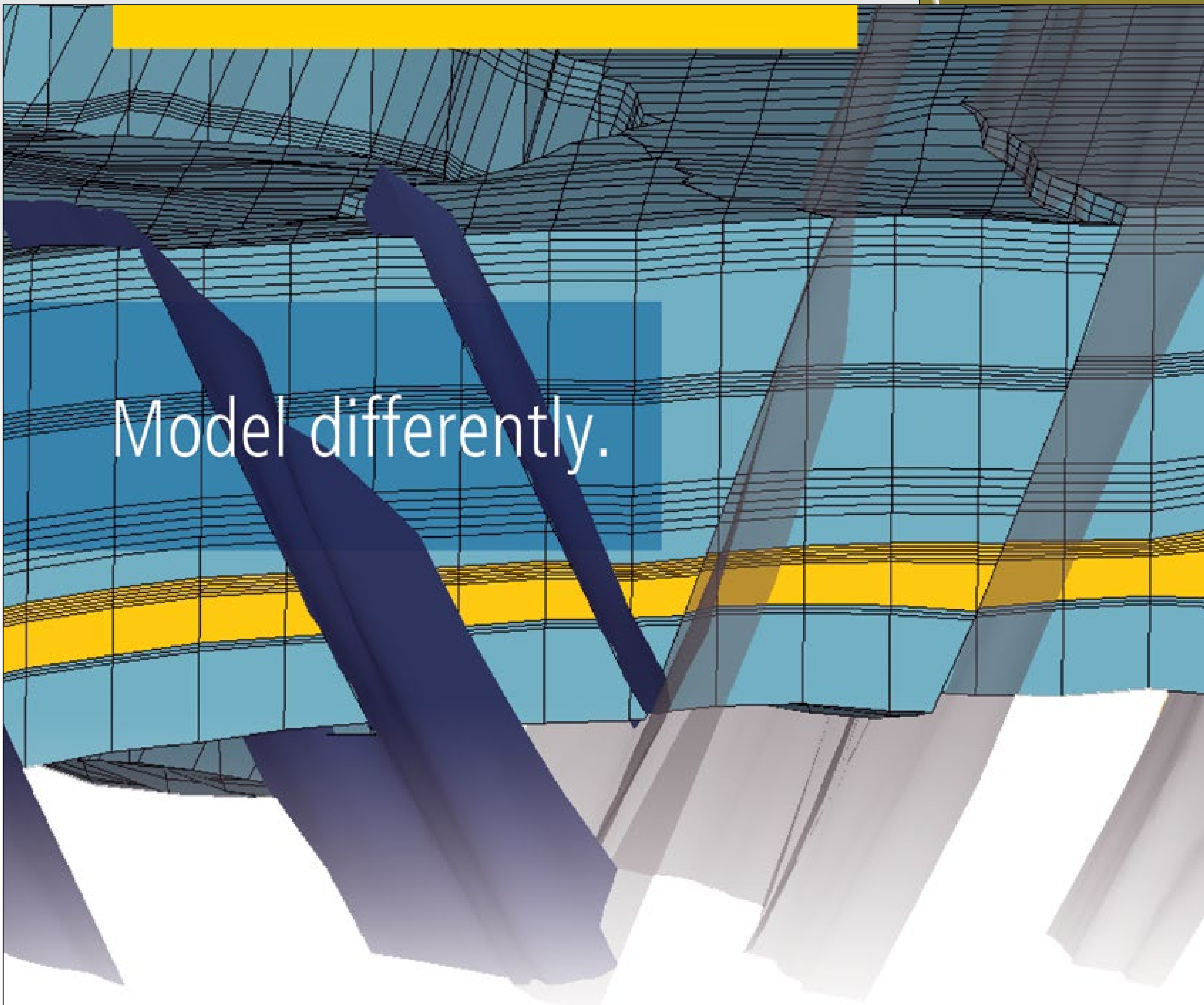
The Stanford study of induced seismicity in Oklahoma took more than two years to complete, according to Walsh. He said it began with an examination of microseismicity – intentionally caused small quakes like those resulting from hydraulic fracturing.

"That was sort of our jumping off point. We started looking at Oklahoma simply because that's where the most earthquakes are," he explained.

Oklahoma averaged fewer than two earthquakes of magnitude 3 (M3) or greater per year between the beginning of modern seismic recording in 1974 and 2008. By 2013, the number of M3 or larger quakes had increased to more than 100, and by 2014 to more than 500.

Six areas of the state were selected for the Stanford study, each 5,000 square kilometers and each seismically active.

See **Seismicity**, page 10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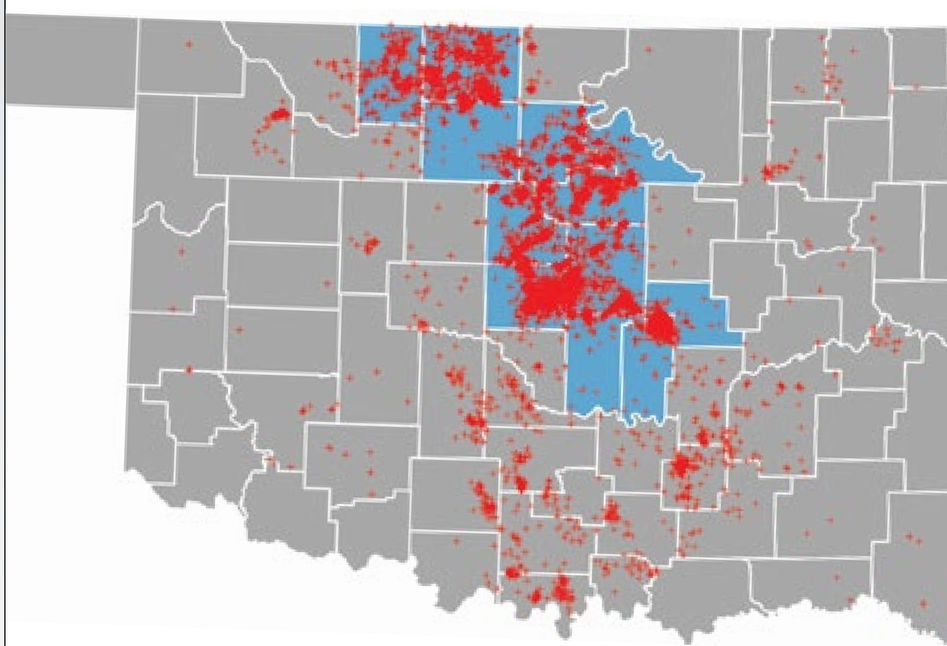


Seismicity Events Rise in Oklahoma

By KEN MILAM, EXPLORER Correspondent

Amberlee Darold has never felt an earthquake, but she has some feelings about the rate at which they have increased in Oklahoma.

"Certainly it's exciting – also overwhelming, perplexing and frustrating," she said.

A research seismologist with the Oklahoma Geological Survey, Darold has been studying the increase in seismicity that has attracted the attention of scientists around the globe.

She will present the results of a recent study at the upcoming Mid-Continent Section meeting in a session called "Seismicity Rates in Oklahoma: A Look at the Seismicity Increase of 2014."

A Record-Setting Year

"Thus far (as of Aug. 10, 2015), we, the OGS, have located 634 earthquakes of a magnitude 3.0 or greater. In 2014 we located 585 earthquakes of a magnitude 3.0 or greater," she said.

The state's seismicity rate for 2014 was greater than any previous year, including those that already had seen a significant increase.

"Overall the seismicity rate in 2013 was 70 times greater than the background seismicity rate observed in Oklahoma prior to 2008. While unlikely, this rate could have been potentially explained by natural variations in earthquake rates from naturally occurring swarms. The current seismicity rate is now about 600 times greater than the background seismicity rate mentioned above," Darold said.

"We at the Oklahoma Geological Survey believe the rates and trends in seismicity are very unlikely to represent a naturally occurring process," she said.

"Most likely, waste water injection wells are the cause for the increase," she said.

In 40 of the state's 77 counties, 5,417 earthquakes were reported during the year.

Of those, 967 were reported as felt to the OGS or USGS and 585 were of a local magnitude of 3.0 or greater, the report states.

In 2013, 284 earthquakes were reported as felt. In 2012, the number felt was 75. The number felt was around 100 in each of the two previous years, an apparent increase from earlier years, according to the OGS.

Speaking on a cellphone from the field, where she was checking on some of the agency's network of about 40 seismometers, she said: "Nowhere else in the world sees the concentration that Oklahoma is seeing. There's no comparison," Darold said.

Potential Causes

The increased activity correlates with the areas of two major oil plays, the Mississippi Lime play and the Hunton dewatering play, she said.

Darold said that about 70 percent of the wastewater is being injected into the Arbuckle, which lies directly above the basement rock.

The increased pore pressure decreases the effective stress in the basement rock and, she said, "Basically, you're pushing that fault to failure."

The Oklahoma Corporation Commission (OCC) has been working with disposal operators in areas of most interest, and more than 50 disposal wells found to touch the basement have plugged back their depths to the Arbuckle. Others have cut their volumes, according to various news reports.

Darold said it is too early to tell if mitigation efforts are working.

"Statistically speaking, there is no clear sign that seismicity is decreasing," she said.

She would not speculate on how long it would take to know if mitigation efforts are effective.

See Rising Numbers, page 10

Rising Numbers

from page 8

While most of the temblors have been relatively weak, a 5.6 earthquake was recorded in 2011. The last time anything close to that magnitude occurred in Oklahoma was a 5.2 quake in 1952.

"Both caused damage, but luckily no lives were lost," Darold said.

"As seismologists, we can't predict earthquakes. We need more knowledge, but we assume we could see another 5.5," she said.

"We at the OGS are not a regulatory agency; we are a state agency for research and public service. Examining the seismicity rates will give us, the OCC and operators insight to the effects of mitigation efforts currently under way," she said.

Increased seismicity has been noted in other regions associated with petroleum or geothermal activities, but none to the extent experienced in Oklahoma, she said.

Knowledge gleaned from the Sooner state experience could prove useful elsewhere.

"Geology does not stop at the state line," she said.

The increased seismicity – and the attention it is getting – is broadening researchers' knowledge base.

"Honestly, we're learning a lot about the faults from the seismicity we are seeing," Darold said.

"It's not exactly an 'upside,' but it is showing us a lot about the faults in Oklahoma – and it's a great research playground for people all over the world." E

Seismicity

from page 6

Just three of those areas included 71 percent of the greater than M3 earthquakes ever recorded in Oklahoma.

Getting good data for the study proved challenging, Walsh noted. Some injection wells were duplicated in state reports, some weren't reported and some had obvious entry errors. Lags in the reporting system made data timeliness less than ideal.

"There's a delay between when the injection happens and when it's aggregated and reported," Walsh said. "That was one of the bigger issues we brought up."

Fortunately, the percentage of errors was small and the study report said fewer than 100 monthly injected volumes, out of 1.5 million, had to be adjusted.

Walsh said the data corrections might not have been perfect, "but we convinced ourselves that we did it well enough to clearly see the overall picture."

And when they analyzed the injection well data and locations in conjunction with the earthquake data, the connection between the two was obvious.

"As soon as we plotted the right data," Walsh said, "it jumped out at us."

Water, Water Everywhere

Under the assumptions in the study, water used in hydrofracturing in the six areas accounted for a small portion of the injected saltwater. Total injected flowback approached 20 percent in only one of the study areas.

Oklahoma includes several plays that produce significant water, including an extensive dewatering project in the Hunton Reservoir, Walsh noted.

"There are plays like the Mississippi Lime where there's high water cut from the beginning because you're producing from a paleo reef," he said. "In the Hunton play, dewatering is an entirely different process from hydraulic fracturing."

While just a subset of faults in crystalline basement are potentially active, the Oklahoma study areas include stressed faults that have a history of non-negligible seismicity, Walsh and Zoback found.

"In the context of critically stressed crust, small perturbations of fluid pressure have the potential to initiate slip on pre-existing faults that are already close to frictional failure. The stresses on the faults are the result of natural geologic processes – the same process that results in naturally occurring seismicity in other intraplate areas," they wrote.

"We understand that the size of the earthquake is going to depend on the size of the fault and the stresses on the fault, which depend on its slip history," Walsh said.

Further studies could help pinpoint the specifics of induced seismicity in Oklahoma, according to Walsh. He said geoscientists and petroleum engineers have reached a high degree of expertise in generating relevant models.

"The limiting factor isn't their ability and knowledge," he said. "Really, the limiting factor is having the right kind of data."

Shared Responsibility

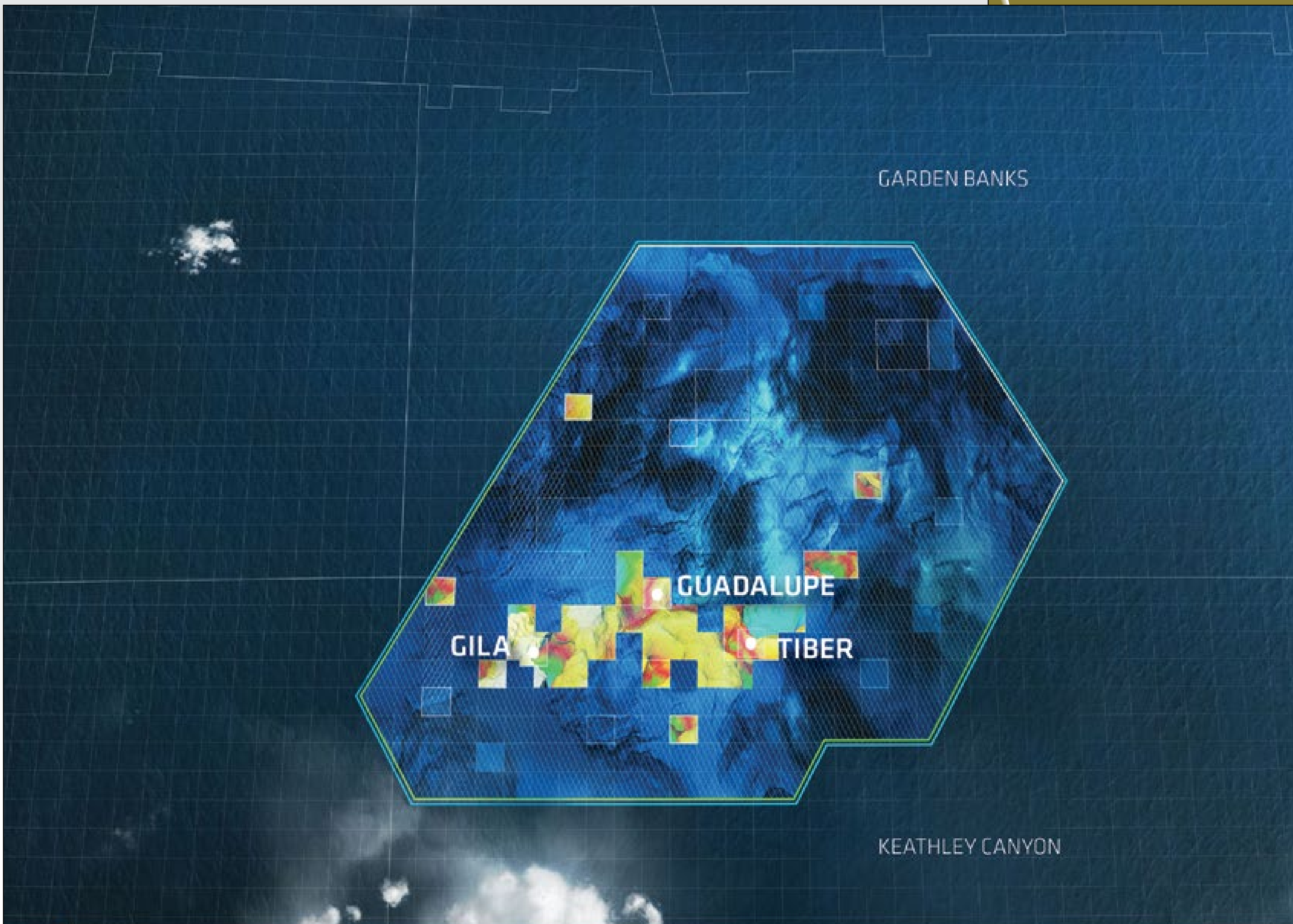
Researchers at Stanford are working to identify the critically stressed active faults in Oklahoma, "to empower the operators," Walsh said.

He believes future earthquake activity could be minimized without halting injection operations – for instance, by injecting wastewater back into producing formations instead of the Arbuckle.

"One of the things we have said is that injecting into the producing formation is one of the biggest no-brainer ways to continue the injections," Walsh said.

But the study findings aren't comforting to those who believe Oklahoma's earthquake activity can be stopped simply by reducing injections at a few wells. Surrounding or nearby wells also might be contributing to the stress perturbations.

"Now," Walsh said, "you need to worry about what the people around you are doing." E


GARDEN BANKS
GUADALUPE
GILA
TIBER
KEATHLEY CANYON

Adding value with azimuthal attributes

Leveraging the 'Hidden Dimension' 3-D Seismic

By HEATHER SAUCIER, EXPLORER Correspondent

Many in the 3-D seismic business are familiar with the offset dimension in seismic data because they work with pre-stack offset gathers on a routine basis. Fewer, however, recognize the other important dimension located in these offset traces: the azimuthal dimension.

While the seismic industry has traditionally ignored the azimuthal dimension, it is now beginning to recognize this important consideration in seismic data processing.

Calling the azimuthal dimension the "hidden dimension" in 3-D seismic data, Bill McLain, vice president of Seismic Processing at Global Geophysical Services said that if recognized and properly processed for, far-angle, wide-azimuth data will respond with more accurate offset amplitudes and rock property attributes.

It can also provide new azimuthal attributes that serve as proxies for differential horizontal pressure, fractures and even fluid types. This improved set of offset and azimuthal attributes, when combined using a multi-variant statistical approach, can lead to improved production prediction models.

And, the ability to better predict production – especially sweet and sour spots – allows for strategic well placement and completion strategies, which will lower field development costs over time.

Operators are already adopting elements of this production prediction attribute approach by geo-steering through the production prediction volume and skipping certain stage completions, which has led to increased production at lower cost, McLain said.

He made his case for "squeezing more information from 3-D seismic data" at the Landmark Innovation Forum and Expo in Houston in August. In a presentation titled, "Leveraging 3-D Seismic for Lower Field Development Costs," he took audience members down a highly technical path toward the proverbial pot of gold.

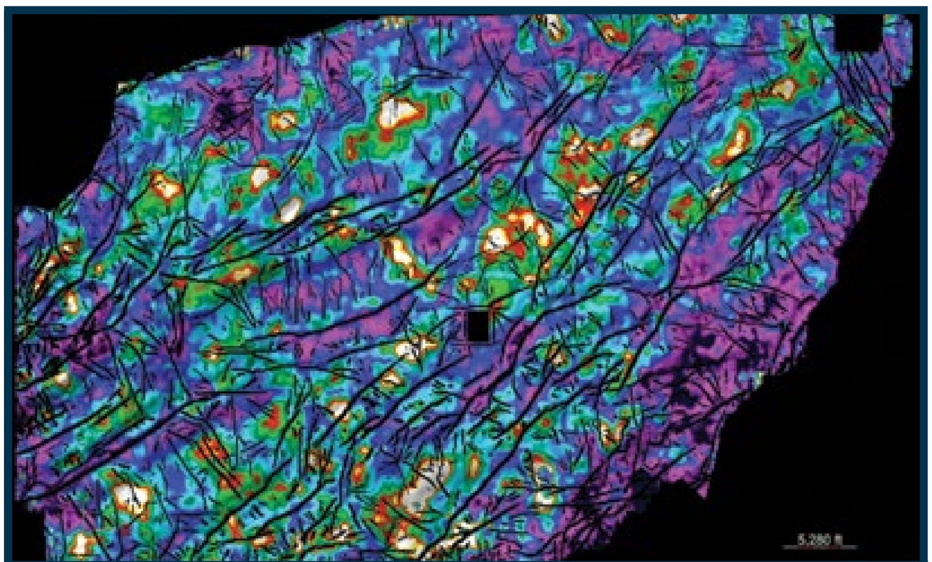
"Everybody," he said, "needs to start thinking about the hidden dimension in seismic data."

Evolution of 3-D Seismic

For the past decade or more, 3-D seismic data has been used to locate sweet spots in unconventional reservoirs. Yet, how the data is acquired, processed and interpreted can have an enormous impact on success, McLain said.

The secret lies in acquiring far-angle, wide-azimuth data. This richer type of seismic data captures more information at each sub-surface image point than would otherwise be captured during seismic data acquisition.

"In the past, this type of data was difficult and costly to acquire because of the limitations of cabled recording systems," McLain said. "Yet, today's autonomous nodal recording systems are much more flexible and have nearly unlimited scalability – making wide-azimuth data much easier to acquire at little or no additional cost. "It has helped to generate better images and new attributes" he added, because it



Map view of the magnitude of azimuthal anisotropy (colors) co-rendered with fault probability (black lines) over an 80 square-mile area of the Eagle Ford in south Texas. Warmer colors such as red, orange and yellow represent higher levels of azimuthal anisotropy.

fundamentally contains more information than narrow-azimuth data typical of older cabled systems."

Advances in seismic processing, including regularization strategies and solving for seismic anisotropy, also play a critical role in leveraging 3-D seismic data. So does the methodology in combining traditional rock properties, such as ductile-brittleness, with azimuthal variations in amplitude and velocity, which reveals valuable information about fractures, overpressure and fluids, and ultimately leads to a more accurate production prediction attribute and new field development strategies, McLain said.

Wide-azimuth data acquisition greatly enhances the predictive ability and accuracy of the resulting 3-D seismic data. Once one can accurately predict hydrocarbon production numbers, then the processes of well placement and stage completions become much more cost effective, versus pattern drilling and well completions, McLain said.

"This new strategy increases overall production of the well and lowers the cost of the well at the same time," he said. "More production and lower costs mean improved efficiency and may allow certain field development economics to work even at these lower oil and gas prices."

Even if oil hovers around $38 a barrel, the cost of acquiring wide-azimuth data remains beneficial to a field development operation, McLain said.

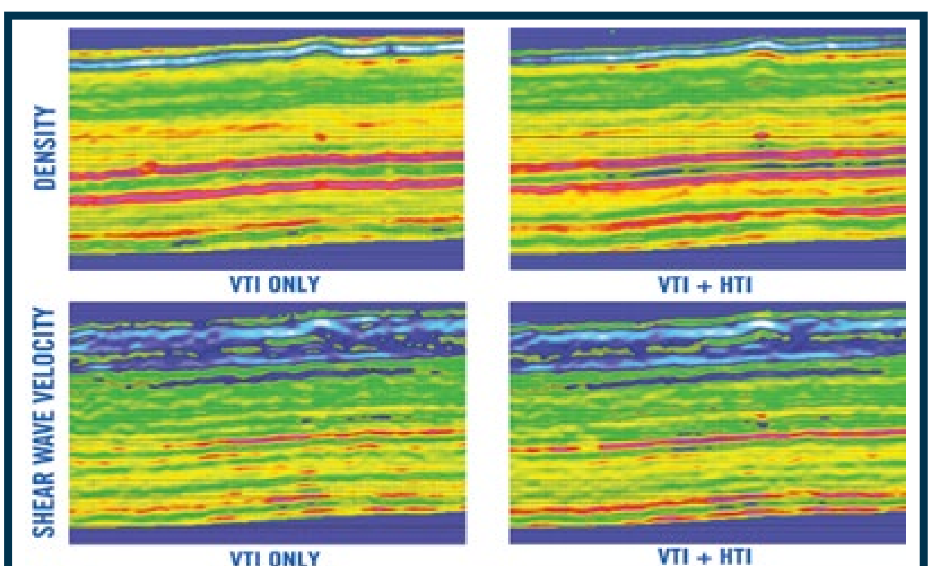
"The added cost for this additional data is quite small compared to the uplift in the accuracy of the 3-D seismic to predict production and how this accuracy impacts well placement and completion strategies," he said.

Anatomy of Anisotropy

There are two types of anisotropy typically found in seismic data: vertical transverse Isotropy (VTI anisotropy), and horizontal transverse Isotropy (HTI anisotropy).

VTI anisotropy is caused by vertical versus horizontal velocity differences in the subsurface, and it distorts reflection arrival times in seismic data with earlier than expected times, especially in the far-angular offsets. This type of anisotropy is best seen on offset gathers and is usually referred to as the "hockey-stick" effect, McLain said.

HTI anisotropy is caused by horizontal variations in velocity in the subsurface and manifests itself as small timing distortions in 3-D seismic data, especially on the far-angular offsets. However, it is best seen on shot-receiver azimuthal image gathers, in which the reflected



Offset amplitude inversion of the Fort Peck 3-D seismic data showing the rock property attributes density and shear-wave velocity, extracted at and around the Bakken interval.

energy arrives in a sinusoidal pattern, with a fast direction (early arrival time) and a slow direction (delayed arrival time), he explained.

Correcting for both VTI and HTI anisotropy produces flat gathers in both offset and azimuth, resulting in sharper images even at far-angular offsets. Clearer seismic data produces more accurate traditional rock properties – ultimately resulting in better production models, which positively impact field development strategies and result in lower costs, he said.

Not solving for both VTI and HTI anisotropy essentially means that valuable pieces of information are being left on the table and that distortions will continue to skew seismic data.

"We have lots of anecdotal feedback from clients in the Marcellus, Eagle Ford and Niobrara unconventional plays where pattern drilling hits one of these HTI anisotropy anomalies, and production just spikes," McLain said.

A Patented Approach

In 2005, Weinman Geoscience, which was acquired by Global Geophysical in 2008, became the first service company to incorporate HTI anisotropy into its imaging algorithm. After successfully solving a strong anisotropy imaging problem in Cook Inlet, Alaska this technology received a patent in 2007, McLain said.

The approach seeks to quantify at each image point (i.e., common mid-point, time sample) within the seismic volume the two attributes that describe root mean square (rms) HTI anisotropy: Vfast azimuth, or the direction of anisotropy, and the ellipticity factor, or the magnitude of anisotropy.

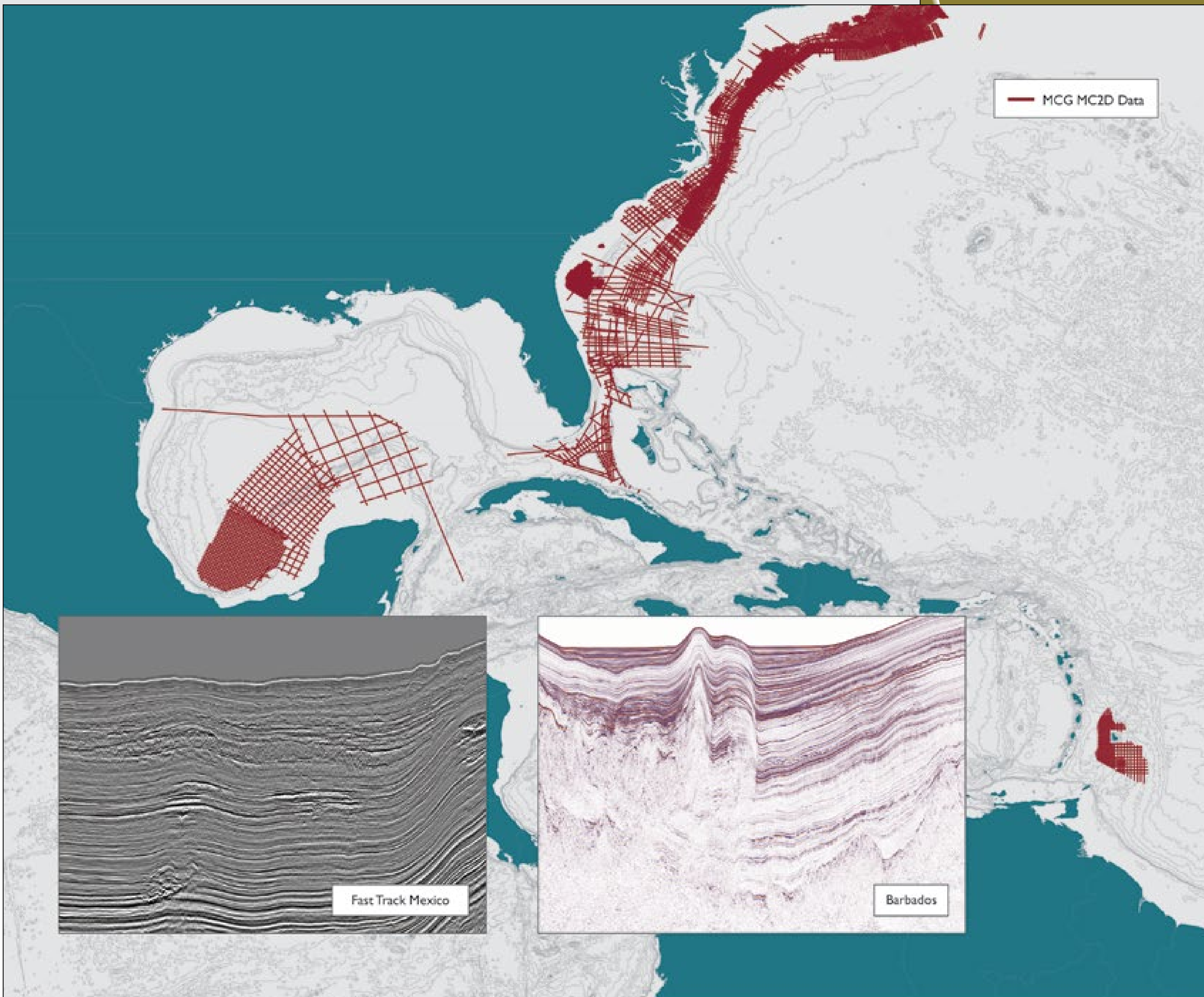
The algorithm measures HTI anisotropy by systematically imaging the data using different combinations of HTI parameters and then determining which azimuth/factor pair maximizes stack power at each output image point, McLain said.

Because ranges of likely HTI parameters are systematically scanned, the approach has become known as "Migration Scanning Analysis," and it uniquely incorporates the anisotropy into the HTI analysis itself, he added.

"Several service providers are now creating reservoir anisotropy properties," McLain added. "But Global is winning validation studies where we tie our interval anisotropy attributes to well control that has either FMI or cross-dipole sonic information, which gives us confidence that we are doing things correctly."

Ultimately it is production prediction that validates the azimuthal attributes best, McLain added.

"When we add the HTI azimuthal attributes into the multi-variate statistical analysis to predict production, the correlation coefficient of actual production versus predicted production always goes up," he said. "This tells us that azimuthal attributes derived from far-angle, wide-azimuth data are adding value to the process of production prediction, and that sweet and sour spots are more accurately being identified." E


MCG MC2D Data
Fast Track Mexico
Barbados

Surprising no one ...

Downturn Hammers Geophysical Industry, Too

By LOUISE S. DURHAM, EXPLORER Correspondent

In the current oil market, much ink has been devoted to operators pulling back on drilling activity and selling off assets, including prime pieces of property.

But what about the geophysical side of the business?

Seismic surveys and data, for instance, are crucial to exploration.

But when exploration slows and actually halts in some places, explorers aren't expected to ink pricey seismic contracts and other services. At best, they'll bring all of their bargaining skills to the negotiating table in an attempt to get more for less.

There has been some buzz about how the downturn is actually a *good* thing, giving everyone in the oil industry time to regroup and focus more on cutting costs, ramping up R&D and becoming more efficient overall.

This is nonsense, according to industry veteran Jim White, president of Houston-based ARKeX.

"We (industry) are barely keeping the lights on," he noted with dismay. "The notion that we benefit from a refocused downturn is a farce."

Not Your Father's Downturn

"This time is different," White emphasized. "I've never seen it happen quite so dramatically as this go-around. We're in a position where companies are going to start going by the wayside."

And, in fact, it's already happening.

Certain operating companies continue to announce cutbacks, and they are accompanied by some of their geophysical brethren.

ION Geophysical, an established firm outside of Houston, is a recent casualty, announcing a 25-percent reduction in its workforce.

Tom Fleure, senior vice president of geophysical technology at Global Geophysical Services, shared some of his observations about the current tumultuous times.

"Some of our clients are going through a lot, even the big guys," he said.

"From a contractor's point of view, business is down at least a half and maybe as much as 70 to 80 percent from a couple of years ago," he noted.

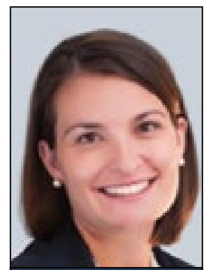
Research and Development

"From a technology point of view, it doesn't mean you stop working on new stuff," Fleure commented. "We're still going forward with our own R&D and engineering."

"In this business, you're dead if you stop, because all will go by you when this turns around," he added.

Software and algorithms take manpower, but not huge capital investments, so Fleure predicts companies will spend available funds on software as opposed to hardware.


WHITE


MARTIN

But, there's a problem when it comes to bringing in and retaining the needed software developers.

"We're competing with other industries, and these guys are hard to get," Fleure noted. "Others see what's happening to our industry, and there are other industries they can go to."

Global concentrates on the surface rather than downhole. Fleure explained that microseismic tends to dominate their conversations with clients today, particularly with regard to microseismic data's contributions to shale plays.

Among other areas of expertise, Global pushes the access-constrained targets, using roads and trails for vibroseis rather than offroads, which can be problematic. Think of the West, for example, where the BLM controls offroad access.

The resulting 3-D is chaotic, or pseudo-random, and it's price-driven.

"We have a lot of clients who want to do 3-D but don't have much budget," Fleure said, "so this way they get 3-D at a lower cost."

He emphasized that this is an effort being used at Global, and not necessarily an industry trend.

Workforce, Technological Impacts

Of course, current market conditions are particularly challenging for anyone trying to start their careers in the geophysical industry, and in the oil and gas industry in general.

"Newcomers coming in to see it deteriorate are not apt to weather this storm," White predicted. "It will be a wake-up call for young guys who say they don't want to go through this. Many of the veterans are leaving, too.

"We've done a poor job of managing supply and demand, so the oil companies win and get stuff cheaper and take advantage," he said.

"The one thing, maybe, new blood might bring to the equation is the outlook to deviate from the norm and change our approach to doing business by not bringing more capacity into the equation and going back to the same old things," he noted optimistically.

When asked about new technology, which will continue to be a must-have, White predicted that much of it will

See **Upbeat Prediction**, page 22

Massive Magma Reservoir Discovered Beneath Yellowstone

By KEN MILAM, EXPLORER Correspondent

The discovery and imaging of a mammoth magma reservoir beneath the Yellowstone supervolcano is a capstone to decades of research, said geophysicist Robert B. Smith.

Smith should know – he's been studying the Yellowstone system for 55 years.

Scientists have long known of a smaller magma chamber, but the new chamber – 4.4 times larger – helps answer the questions about the volcanic system.

"It's the first time we've completed a whole 3-D image completely through the crust," Smith said.


SMITH

Smith, researcher and professor emeritus at the University of Utah, is a co-author of a paper discussing the study, published earlier this year in the journal, Science.

The study utilized seismic tomography from years of earthquake data to create images similar to a CT scan of the earth, he said.

The Largest Risk

While the discovery garnered headlines because of public fascination with the supervolcano, Smith said the study doesn't change the risk assessment of a catastrophic eruption: 1 in 700,000 in any given year.

"That's pretty small," he said.

But it also shed light on a more immediate hazard, he said.

"People don't appreciate the largest risk: earthquakes," he said. "Earthquakes occur in and around these big faults with a frequency that is much higher. They are a much higher risk and higher hazard than volcanoes.

"A 7.3 earthquake in Yellowstone in 1959 killed 28 people," he said. "There's been no volcanic eruption in 70,000 years."

Thomas A. Drean, AAPG member and director of the Wyoming State Geological Survey, agreed.

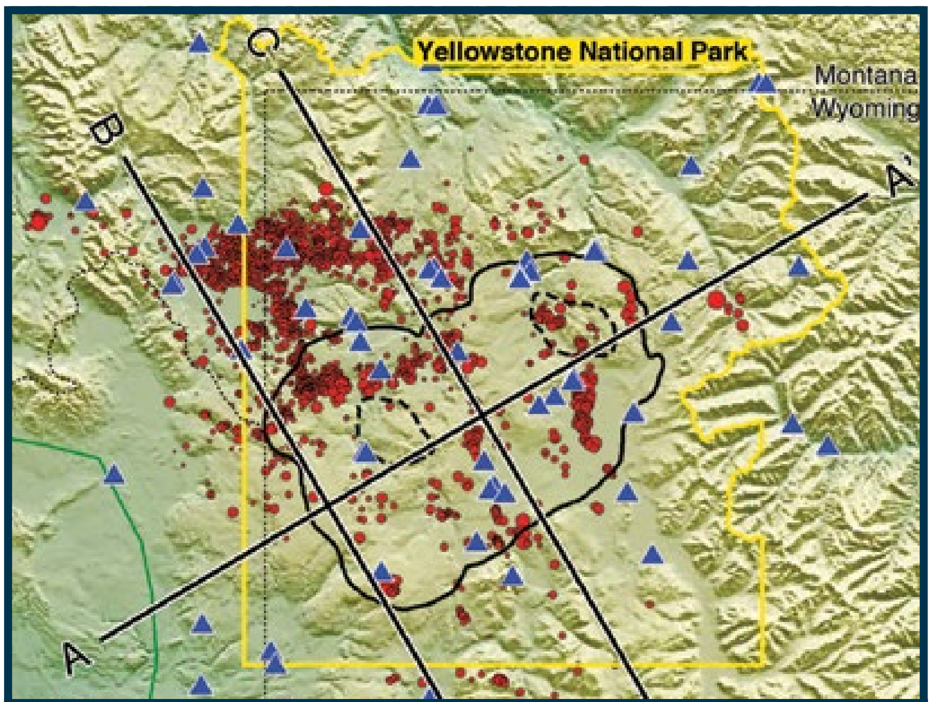
"The reason we monitor in Wyoming and monitor Yellowstone is not only curiosity. The biggest issue for us is public health and safety and associated geological hazards," Drean said.

"The biggest takeaway (in the study) for people, and yes, a nice addition for us, is that it has not increased the risk or hazard probability," Drean said.

A New Working Model

The newly found reservoir lies 12 to 28 miles below the supervolcano. In a University of Utah press release, co-author Jamie Farrell said the hot rock in it could fill the Grand Canyon 11.2 times over.

"For the first time, we have imaged the continuous volcanic plumbing system under Yellowstone," said first author Hsin-Hua Huang, also a postdoctoral researcher in geology and geophysics. "That includes the upper crustal magma chamber we have seen previously plus a lower crustal magma reservoir that has never been imaged before and that connects the upper chamber to the Yellowstone hotspot plume below."



Map of the seismic stations used in this study and the P-wave velocity cross-section locations in the Yellowstone area.

"We now have a new working model" for Yellowstone and other volcanic systems, Smith said.

The magma chamber and reservoirs are filled with hot, mostly solid rock like a sponge, Smith said, with molten rock filling the pockets.

The upper chamber is about 2 percent melt while the upper chamber is about 9 percent melt. That matches earlier predictions, according to the authors.

Smith said the study is the result of advances in methodology and new data gathered over years by several cooperating entities.

A seismic array 200 and 300 kilometers wide uses data from about 60 stations, with installation begun in 1983, he said. In that time, seismic data has been gathered from some 45,000 Yellowstone quakes.

"It's high-quality data collected in real time at the University of Utah," he said. "We provide the data and the public has access to it immediately."

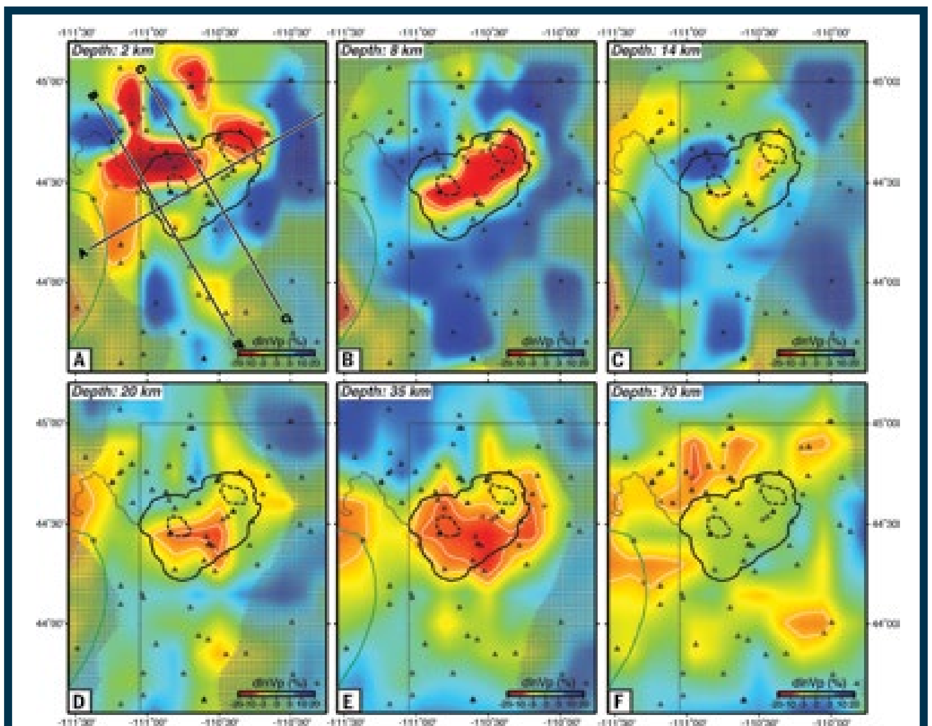
Before the new discovery, researchers had envisioned partly molten rock moving upward from the Yellowstone hotspot plume via a series of vertical and horizontal cracks, known as dikes and sills, or as blobs, the authors said. They still believe such cracks move hot rock from the plume head to the magma reservoir and from there to the shallow magma chamber.

The new study employed a technique developed by Huang to combine seismic information from local quakes detected in Utah, Idaho, the Teton Range and Yellowstone by the University of Utah Seismograph Stations with data from more distant quakes detected by the National Science Foundation-funded EarthScope array, which was used to map the underground structure of the lower 48 states.

The Utah seismic network has closely spaced seismometers that are better at imaging the shallower crust beneath Yellowstone, while EarthScope's seismometers are better at making images of deeper structures.

The Yellowstone System

As the authors explained, this is how the new study depicts the Yellowstone system, from bottom to top:



Depth slices of the Yellowstone tomographic P-wave model.

▸ Previous research has shown the Yellowstone hotspot plume rises from a depth of at least 440 miles within the Earth's mantle. Some researchers suspect it originates 1,800 miles deep at Earth's core.

The plume rises from the depths northwest of Yellowstone. The plume conduit is roughly 50 miles wide as it rises through the Earth's mantle and then spreads out "like a pancake" as it hits the uppermost mantle about 40 miles deep.

Earlier Utah studies indicated the plume head was 300 miles wide. The new study suggests it may be smaller, but the data aren't good enough to know for sure.

▸ Hot and partly molten rock rises in dikes from the top of the plume at 40 miles' depth up to the bottom of the 11,200-cubic-mile magma reservoir, about 28 miles deep. The top of the newly discovered blob-shaped magma reservoir is about 12 miles deep, Huang said.

The reservoir measures 30 miles northwest to southeast and 44 miles southwest to northeast.

"Having this lower magma body resolved the missing link of how the plume connects to the magma chamber in the upper crust," co-author Fan-Chi Lin said.

▸ The 2,500-cubic-mile upper magma chamber sits beneath Yellowstone's 40-by-25-mile caldera, or giant crater. Farrell said it is shaped "like a gigantic frying pan" about three to nine miles beneath the surface, with a "handle" rising to the northeast.

The chamber is about 19 miles from northwest to southeast and 55 miles southwest to northeast. The handle is the shallowest, longest part of the chamber that extends 10 miles northeast of the caldera.

Scientists once thought the shallow magma chamber was 1,000 cubic miles. But at science meetings and in a published paper this past year, Farrell and Smith showed the chamber was 2.5 times bigger than once thought. That has not changed in the new study.

Discovery of the magma reservoir below the magma chamber solves a longstanding mystery: Why Yellowstone's soil and geothermal features emit more carbon dioxide than can be explained by gases from the magma chamber.

Farrell said a deeper magma reservoir had been hypothesized because of the excess carbon dioxide, which comes from molten and partly molten rock.

Smith said the next step is integrating global positioning system data with GPS array paralleling the seismic.

He added that the reservoir discovery is gratifying, combining years of data collection and putting together computer programs and instrumentation from many people and agencies.

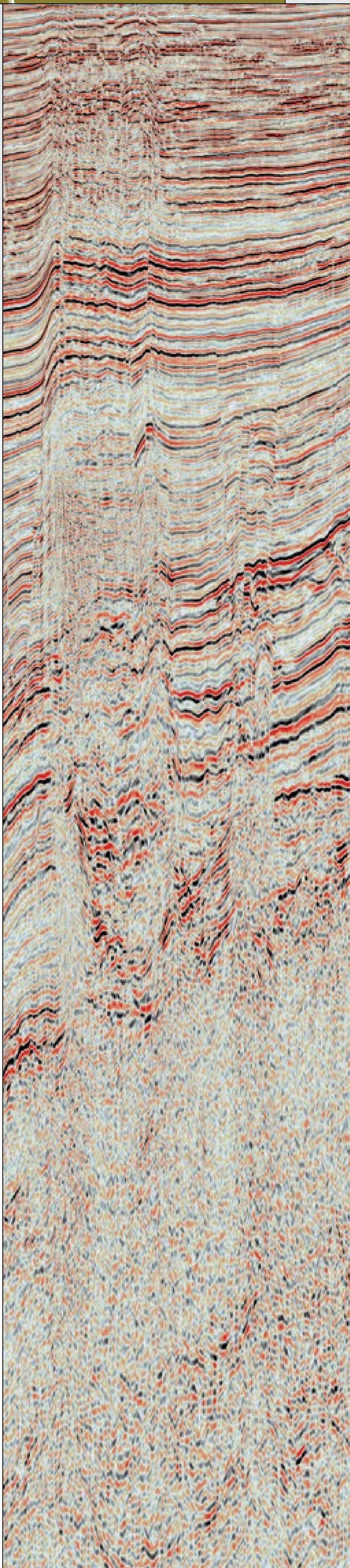
He said at least 30 graduate students have done theses based on the Yellowstone research.

"It's a long record and it really paid off in this paper," he said.

Now 76, Smith said he began studying Yellowstone "just out of high school."

He maintains a full schedule of research, lecturing and field trips and still finds Yellowstone fascinating.

"There's a new discovery every year," he said. "That's what keeps me going." E



GWL's Basin-Wide surveys - deep insight into exploration understanding

Time to Investigate Deep Horizons.

Geology Without Limits' Unique Approach

By Aleksandr Nikitin and Laslo Miles

The need to replenish the world's proven hydrocarbon reserves requires both the development of promising new areas, and additional exploration of seemingly well-studied areas.

For example, in the Gulf of Mexico for many years only the upper part of the geological section was considered promising and only relatively recently by studying the deeper part, a number of major discoveries have been made (e.g. Great White, Tobago and Silvertip in Alaminos Canyon). Similarly large hydrocarbon accumulations have been discovered in the deep strata of the Brazilian offshore (e.g. Carioca-Sugar Loaf field, the third largest accumulation of oil in the world). These examples clearly show us the direction in which modern seismic surveys should be carried out.

Complex methods used by "Geology Without Limits" (GWL) in the planning and implementation of large regional marine seismic surveys, including gravity and magnetic surveys which are outside the scope of the present article, provides the opportunity to build a high-precision deep geological model of the region under study.

In conventional reflection work, processing geophysicists are limited by streamer length while building deep-depth velocity models in order to investigate the whole sedimentary cover and reveal basement structure, especially in the deep horizons areas, that are the principal points of interest nowadays. Even a 12 km seismic streamer length can be not enough if we are targeting the geological aspects of deep horizons. Seismic interpretation geophysicists and geologists can be restricted by the datasets they have to deal with. As a result, basin models may reflect only minor aspects of the oil and gas fields, leading into the incorrect prediction of oil and gas occurrence and inaccurate estimated reserves.

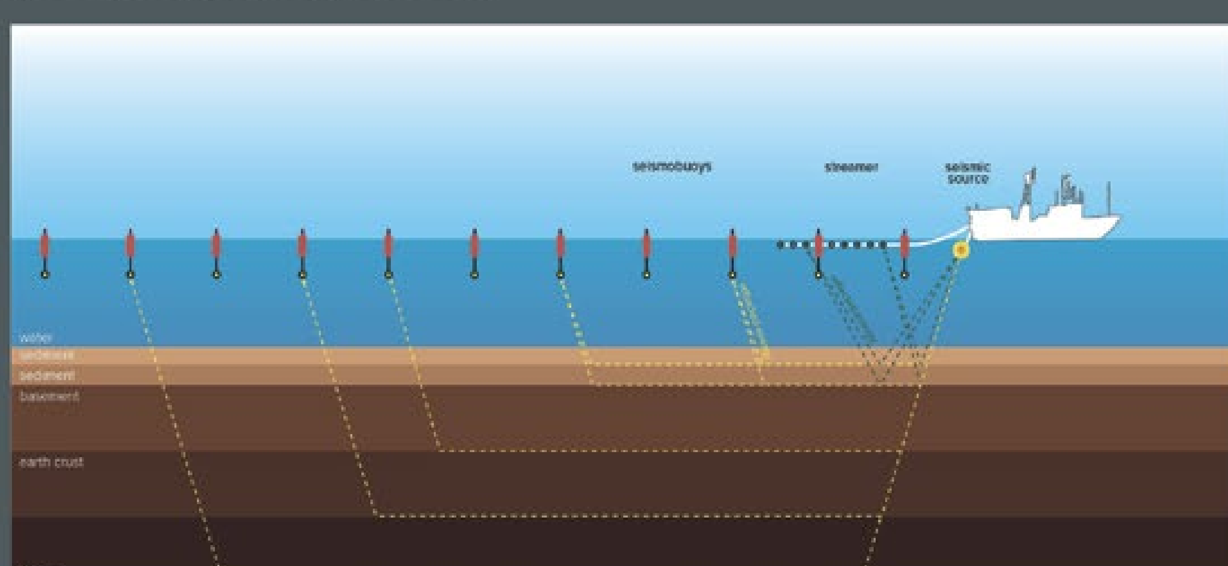


Figure 1 - Overview of GWL Seismobuoy Technique

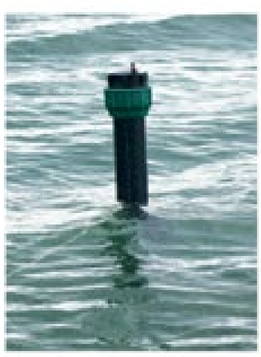
GEOLOGY WITHOUT LIMITS

But what if **we want to go beyond** this and see the bigger picture?

One of the cutting-edge geophysical technologies designed to address the issues described above is a unique refraction seismic data acquisition technique conducted with help of GWL's self-developed seismic recording equipment – **GWL Seismobuoy**.

GWL Seismobuoy helps to triumph over streamer length constraints and extend seismic data offsets up to 150 km, enhancing depth of the survey up to crustal boundaries and the Moho discontinuity.

Adjustable sensor depth makes GWL Seismobuoy flexible to be utilized in various scenarios and hydrographic conditions: from shallow waters and transition zones to deep ocean waters areas and regional basin-wide surveys. Online satellite based tracking position gives an opportunity to follow GWL Seismobuoy and its recording status anywhere anytime you always know where your data is and have total control over it. GWL Seismobuoy's rechargeable battery life is up to 15 days of continuous recording, enabling the acquisition of seismic data on ultra-long (up to 2000 km) 2D regional seismic lines. GWL Seismobuoy's major technical characteristics are represented on figure 2.



Technical Parameter	
Frequency Range	1 - 1 000 Hz
Hydrophone Sensitivity	-191-/+ dBV re 1 μPa @ 20°C, 27.22 V/bar
ADC Resolution	24 bits
Sample Interval	8; 4; 2; 1; 0.5; 0.25 ms
Operating Life (100% charge)	Up to 15 days continuous record

Figure 2 - GWL Seismobuoy appearance and major technical characteristics

A range of tests performed to compare GWL Seismobuoy and industrial Ocean Bottom Seismometers (OBS) (used as a reference point to the obtained seismic data) has proved the concept of the unique refraction seismic data acquisition technique and has shown the excellence of the recorded data by GWL Seismobuoy in comparison to the data recorded by industrial reference OBS (GWL Seismobuoy has higher sensitivity of the sensor and a broader recorded frequency range under equal environmental recording conditions – figure 3). Moreover, geological interpretation of the seismic gathers recorded during one of the tests perfectly matches with a detailed geological survey performed earlier in the project site.

Thus, GWL Seismobuoy has no limits in its utilization whether it is in its initially designed implementation for 2D regional seismic surveys or in the field of 2D/3D engineering seismology studies with applications to geotechnical engineering.

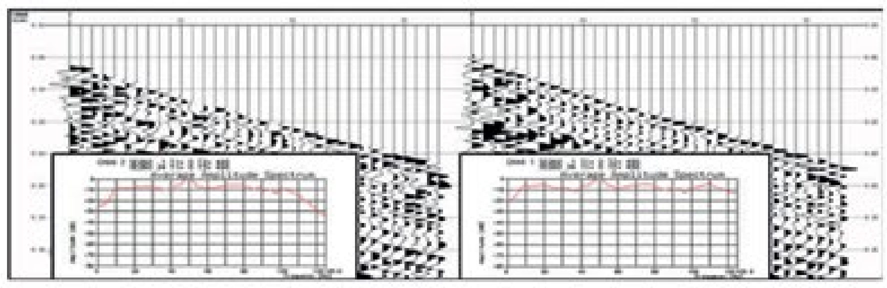


Figure 3 - Sample of common receiver gather after preprocessing designed to refracted waves event picking. Left, OBS with overlaid Average amplitude spectrum. Right, GWL Seismobuoy with overlaid Average amplitude spectrum.

Additionally GWL has developed a unique concept where the simultaneous acquisition of broad-band reflection data and ultra-long offset refraction data along the same seismic lines will provide superior velocity information for the data processing and the geological model building. This concept lends itself particularly to basin-wide investigations and is about to be applied in key complex basins across the world such as the Caribbean.

Flexible seismic design of the refracted wave survey (receivers distance, receivers density, maximal offsets, etc.) can be optimized for an individual geological environment providing the best production conditions and high quality data. Thus, refracted wave seismic data obtained with the same source (specially tuned up to a low frequency spectrum) is easily integrated with reflected wave seismic data on the processing and interpretation stages. Ray tracing modeling and combined reflected and refracted waves seismic tomography are used for advanced velocity imaging (an example of seismic tomography velocity imaging is shown in figure 4). Derived reliable velocity models can be used for migration procedures in the time and depth domains – providing us with a cleaner image of the seismic streamer dataset itself and true position of the deep-depth horizons. Geological horizon mapping including crustal boundaries and the Moho and forward problem solution modeling gives us an opportunity to drive forward renewed regional geologic and geodynamic basin models to the next level.

Figure 4 – An example of sedimentary cover and Moho discontinuity where velocity model's ray coverage derived from joint refracted/reflected waves and seismic tomography velocity imaging

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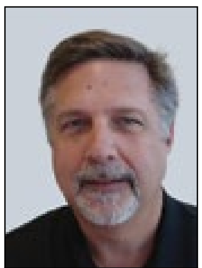
Filling Mexico's 2-D Seismic Gap

By HEATHER SAUCIER, EXPLORER Correspondent

Just after Mexico announced it would open to international oil and gas investors after 76 years of nationalization, exciting exploration plays believed to exist on the Mexican side of the Perdido Fold Belt and in the Bay of Campeche salt basin became of great interest to third-party investors.

Mexico began its first round of bidding last December with one major disadvantage to the bidders: an almost complete lack of seismic data to investigate the detailed regional geology of Mexico.

"Until recently, there has been no seismic data available for companies outside of Pemex," said AAPG member Mark Gresko, former director of geology and geophysics at ION Geophysical, speaking of the country's national oil company Petróleos Mexicanos.

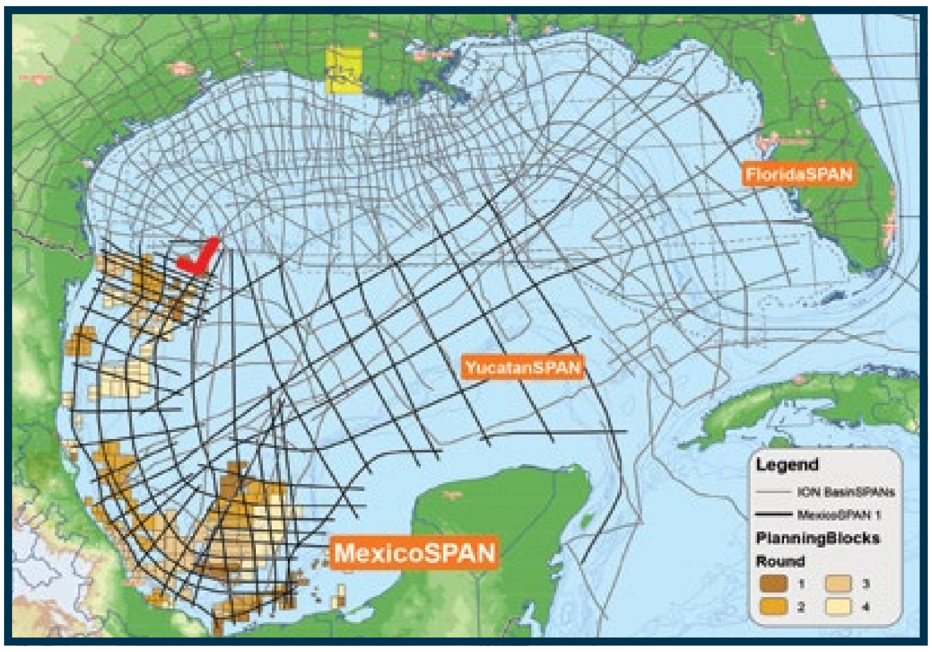


GRESKO

"Mexico is a frontier basin for everyone except Pemex," he said.

Anticipating Mexico's announcement, ION executives partnered with the University of Texas Institute for Geophysics, which conducted a scientific 2-D seismic survey of the southern Gulf of Mexico approximately 30 years ago, and began reprocessing the data at a fast and furious pace – completing the process at the end of 2014.

"ION had insight into the opening of Mexico," Gresko said. "It worked out well for them in the short term."



The seismic survey, formally called YucatanSPAN by ION, was made available to companies looking to understand the regional geology in the southern Gulf of Mexico.

ION followed that effort with the shooting of an extensive 2-D seismic program totaling more than 22,000 line-kilometers throughout the southern Gulf of Mexico.

When combined with the company's existing data from its YucatanSPAN, GulfSPAN and FloridaSPAN packages, the new data from MexicoSPAN will deliver what ION announced recently as "the industry's only complete, basin-wide regional view of the Gulf of Mexico."

Fast-track, pre-stack time migrated (PSTM) data has already been delivered to the underwriters. Final PSTM and pre-stack depth migrated data will be delivered in the first quarter of 2016.

The MexicoSPAN program, which completed acquisition in September, coincides with Mexico's first bidding round and offers operators broad-based insight into Mexico's geology in the Gulf, Gresko said.

"2-D seismic data provides the big picture that tells you about the whole basin," he said. "3-D is looking at things under a microscope."

While Mexico is making available 3-D seismic data for potential investors, Gresko said most geologists want to study data from 2-D seismic to high-grade areas before spending a greater amount of money to take a closer look.

Advantages of 2-D Seismic

Using seismic streamers that are 12 kilometers long, ION has generated a widely spaced and deeply imaged "grid" that bends and curves through significant features in the Gulf of Mexico.

"In order to get the best picture, you shoot a line perpendicular to the structure or feature you are looking at, so the lines curve when the geology underneath has moved in a different direction," Gresko said. "It ends up looking not very grid-like but more like a spider's web."

Long cables allow a geoscientist to "see" deeper into a basin. During the MexicoSPAN project, ION captured 18 seconds of "listening" – as opposed to the more typical 6, 8 or 10 seconds of recording.

"The longer you listen, the deeper you hear, and the deeper you can image," Gresko said, explaining that ION's data reaches depths up to 40 kilometers.

"That's much deeper than you would vertically drill a well," he said. "But it gives you a full picture of the sediments and underlying rocks within the

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Upbeat Prediction

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originate at the universities with funding by the industry.

"For now, the challenge is to focus on what will bring immediate returns," he said. "The last thing we need to be doing is looking for growth opportunities."

Predictions

As to the future, companies with good balance sheets are the ones who will make it through, as will the companies with their own equipment, according to White.

There are some upbeat predictions emanating from the International Association of Geophysical Contractors (IAGC), but there may be a long wait until they're realized.

"IAGC is focused on the overall global energy demand long term," said recently installed IAGC president Nikki Martin.

Martin is the first female to be appointed to this role in the organization's 44-year history.

"It's estimated that by 2040, 80 percent of global energy demand will come from oil and gas," she said. "Meeting energy demands is long term, and that can't be driven by last year, this year or next year's oil prices."

A telling comment about the situation today came when Martin mentioned that, for the first time in a long time, there is not one 3-D survey operating in the U.S. Gulf of Mexico, which some might find to be a tad unsettling, even though there is some activity closer to Mexico, which is now welcoming new operators.

Given the severity of the current down cycle, the industry may look quite different before long.

"One way to look at it is that it's like a cleansing," White said.

"It will promote discussions for consolidation, and to me that's a good thing, " he asserted. "It will be a chance to right the ship and hopefully prepare for the next one, so it won't hurt as much. We need to right-size the amount of supply for the current demand."

And demand for geophysics is sure to increase, according to Martin.

"You can't have successful E&P without the geophysical industry," she said. "So it will remain a critical part of exploration and development of global oil and natural gas resources for many years to come." E

Deeper Data

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basement of the basin."

Geologists reply on 2-D seismic for knowledge such as a basin's age and history, the types of rocks it contains, faults, folds, stratigraphic features and deep crustal images.

The seismic is shot using wide spacing, primarily 10 to 25 kilometers between lines. However, if an important structure is noted, then more closely spaced lines are shot.

Two areas where more detailed geophysical data was gathered by ION are the Perdido Fold Belt and the Campeche salt basin, Gresko said.

"These are places where we know high-quality exploration prospects exist so we put more dense lines there," he said. "A lot of companies have a specific interest in the Perdido area and areas in the south in the Bay of Campeche. While Pemex has drilled a handful of wells in the Perdido fold belt, it has not explored very much in the Campeche salt basin. The geology there is very difficult and complex, but it's very prospective. It looks interesting from an exploration point of view."

Companies that choose to acquire 2-D seismic data and subsequently want to know more about a particular area can request that close-space 2-D seismic be shot, or they can acquire 3-D seismic data, which is now available at Mexico's National Hydrocarbons Commission (CNH).

"Mexico has put together data packages," Gresko said, "but they lack the initial 2-D data that companies need to make their own interpretations and decisions."

Back to Economics

Oil has been proven to be in Mexico. However, the lagging question continues to be how economical it is to produce.

"The hydrocarbon system is there," Gresko said. "The price of oil is key."

On the U.S. deepwater side of the Gulf, there are existing production facilities that make future U.S. discoveries economically viable. However, if new prospective areas are found on the Mexican side, the discoveries must be large enough to support the cost of new infrastructure to move the hydrocarbons to market.

"The United States has been involved in expensive deepwater drilling, but the costs are coming down because of more efficient drilling and development processes," Gresko said. "Producing oil on the Mexican side at $40 a barrel will be challenging. I would think that if prices increase to $60 or $70 a barrel, things will become economical on the Mexican side."

However, even if operators have to wait out the current price of oil, 2-D seismic imaging spanning the entire Gulf of Mexico could assist operators on the U.S. side, Gresko said.

By correlating key U.S. well data with the 2-D Mexican seismic lines, new information about U.S. geology might be revealed. For example, the carbonate reefs of the southern Gulf of Mexico could have similarities to those near Florida, Gresko said. If carbonate plays in Mexico are successful, the same could hold true on the U.S. side.

The key to everything begins with 2-D seismic data.

"It gives you the big picture," Gresko said. "And, when you look at a basin as a whole it helps piece the basin history together. Then you'll make better business decisions as to where to focus your exploration activity and investments." E

Geosteering For Well Placement Efficiency

By LOUISE S. DURHAM, EXPLORER Correspondent

To be successful in the oil industry, producers often need more than intelligence and talent. They need the courage to take risks.

Look at The Woodlands-based Vitruvian Exploration II LLC, for example.

The company acquired about 38,500 contiguous acres in the Woodford South Central Oklahoma Oil Province (SCOOP) shale play in December 2012.

The leased area is in the highly concentrated liquids-rich window of the play, according to Vitruvian president and CEO Richard Lane. He noted the SCOOP area has excellent reservoir rock, so it comes as no surprise when he says the reserves potential is estimated to be 558 MMboe.

The acquisition included about 350 producing vertical wells.

The real challenge lay ahead, though.


LEMKE

Shannon Lemke and her colleagues at Vitruvian Exploration will present "Integration of geosteering and drilling data for well placement efficiency in the SCOOP horizontal Woodford play" at the 2015 AAPG Mid-Continent Section Meeting in Tulsa this month, Oct. 4-6 at the downtown Hyatt Regency Hotel.

Steep Learning Curve

This is unconventional reservoir rock, which generally demands horizontal drilling technology in order to reach its production potential.

The proverbial fly in the ointment was that Vitruvian had no horizontal drilling experience in the deep Anadarko basin, although its staff members had gained expertise in laterals elsewhere.

And in the oil patch, the clock is always ticking loudly.

"We had six months between closing the acquisition and getting the first rig to figure out as much as we could about drilling in the (principally late Devonian-age) Woodford," said Vitruvian staff geologist Shannon Lemke.

"The acquisition included interest and data in 27 horizontal Woodford wells drilled by three different operators," she noted. "The data includes both MWD, gamma ray data and also the surveys for each horizontal well drilled."

Using 40 type logs, the Vitruvian team developed a stratigraphic correlation across the basin so they could split up the Woodford into nine different units. Prior to embarking on their own drilling program, the geoscience team used this framework to build a geosteering database and analyze which Woodford intervals were being targeted by other operators.

Multi-Purpose Geosteering

Although commonly viewed as a means to keep the drill bit on course while traversing the laterals, geosteering also can be used for regional evaluation and optimization of specific target intervals when embarking on a play.

Vitruvian uses a geosteering program from Stoner engineering called SES.

"Using a type log, a survey and gamma ray data, we're able to geosteer each of the wells and determine at any point along the wellbore what part of our stratigraphic framework those wells fit into," Lemke said.

In other words, by utilizing collected data and the software program, post-drill geosteering can be used to determine exactly where a well landed no matter the operator.

"This is what we had to do with the data to get ready to drill our own wells, understanding where all of the offset operators are targeting the Woodford," Lemke said.

Beginning in mid-2014, rate of penetration (ROP) data were integrated with the geosteering data as a means to identify and target Woodford zones of high reservoir quality having more favorable ROP.

"We can see zones that clearly drill faster than others and see how our ROP averages in our wells versus the competition," Lemke noted. "If it's not sufficient, we can tell the drilling department and give them the data."

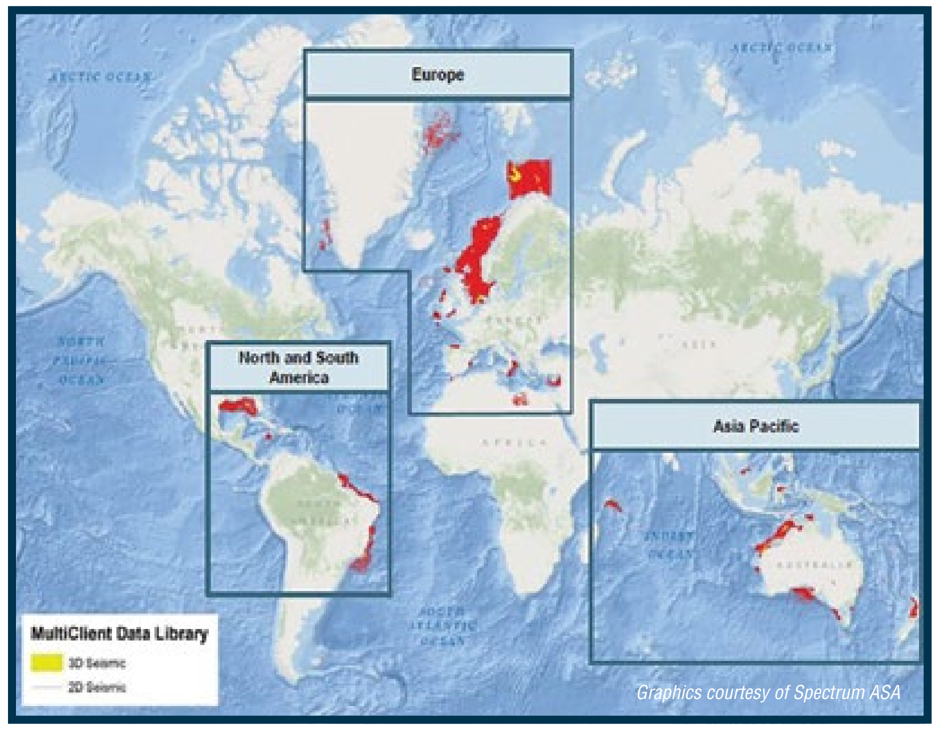
Oklahoma is especially attractive for operators given that owning any interest in a section means you're in a well when it's drilled. Even minuscule land ownership means the company owns a piece of the action.

"We get all the data in every well we participate in, no matter how small our interest," Lemke emphasized.

Even though actually buying the data via participation, the price tag tends to pale in comparison to the value.

When queried as to the wisdom of running four rigs currently, Lemke noted they are hedged for now.

Since Vitruvian began its SCOOP activity, it already has completed 25 company-operated Woodford wells and continues assimilating knowledge on how best to optimize each new well in this area where differences are the rule rather than the exception.



Graphics courtesy of Spectrum ASA

Data Purchase 'Changes Game'

By KEN MILAM, EXPLORER Correspondent

Times may be tough for seismic companies, but not all companies are waiting for the current storm to pass.

Spectrum ASA recently moved to gain a greater global footprint by purchasing Fugro's 2-D seismic library – a move Spectrum CEO Rune Eng called a "game changer" for the multi-client seismic imaging company.

The new library exceeds three million kilometers of 2-D multi-client seismic data.

"Strategically, this was important for (our) growth with increased geographical footprint of data coverage and greater interaction with oil companies," Eng said.

The transaction "ranks us as number 5 in the world in terms of the size of our 3-D seismic library," he said, "with a strong presence in Australia and Norway.

"Spectrum is now a natural speaking partner in most sedimentary basins around the world."

The purchase price was $115 million on a cash and debt-free basis, and was funded by a combination of bank debt and a guaranteed share issue, according to a company statement.

Spectrum agreed to acquire three subsidiaries of Fugro holding the Fugro multi-client data library, as well as certain U.S. multi-client library assets.

The scope of the transaction includes the entire Fugro multi-client library, with the exception of certain non-transferrable items. No employees from Fugro will be transferred to Spectrum as part of the deal.

Eng said the two libraries "entirely complement each other" with minimal overlap, and the data is accessible immediately.

Data quality is of ever-increasing importance in the industry, he said.

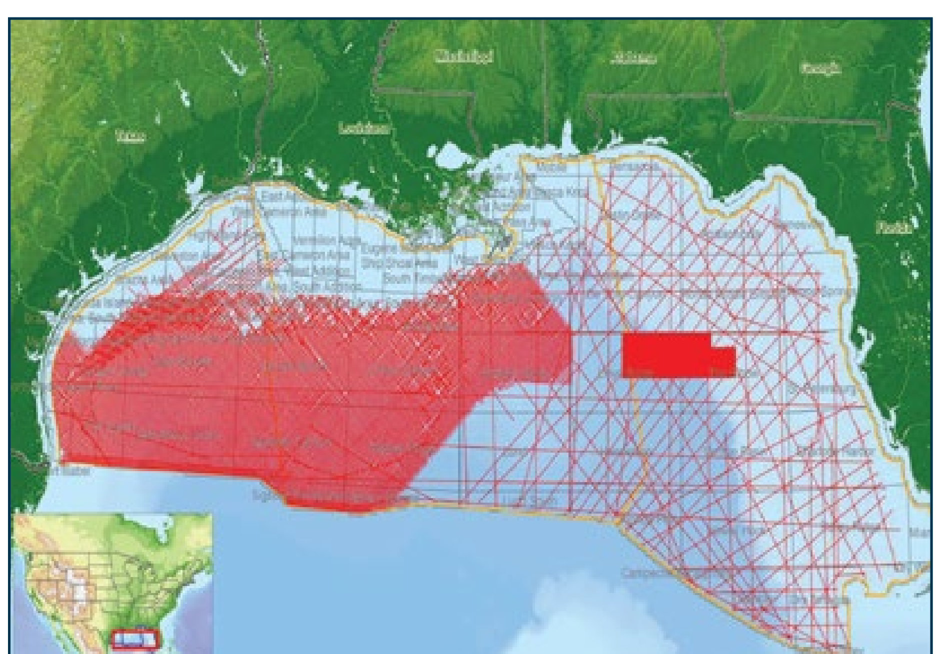
"Many believe that our industry is currently experiencing one of the worst downturns in its history, if not the worst," Eng said. "This is especially evident if you reflect on the overcapacity of vessels in the industry and the anticipated period of lower demand for seismic services.

"We, as a whole, must adapt through ever-higher efficiencies and lower unit costs," he said.

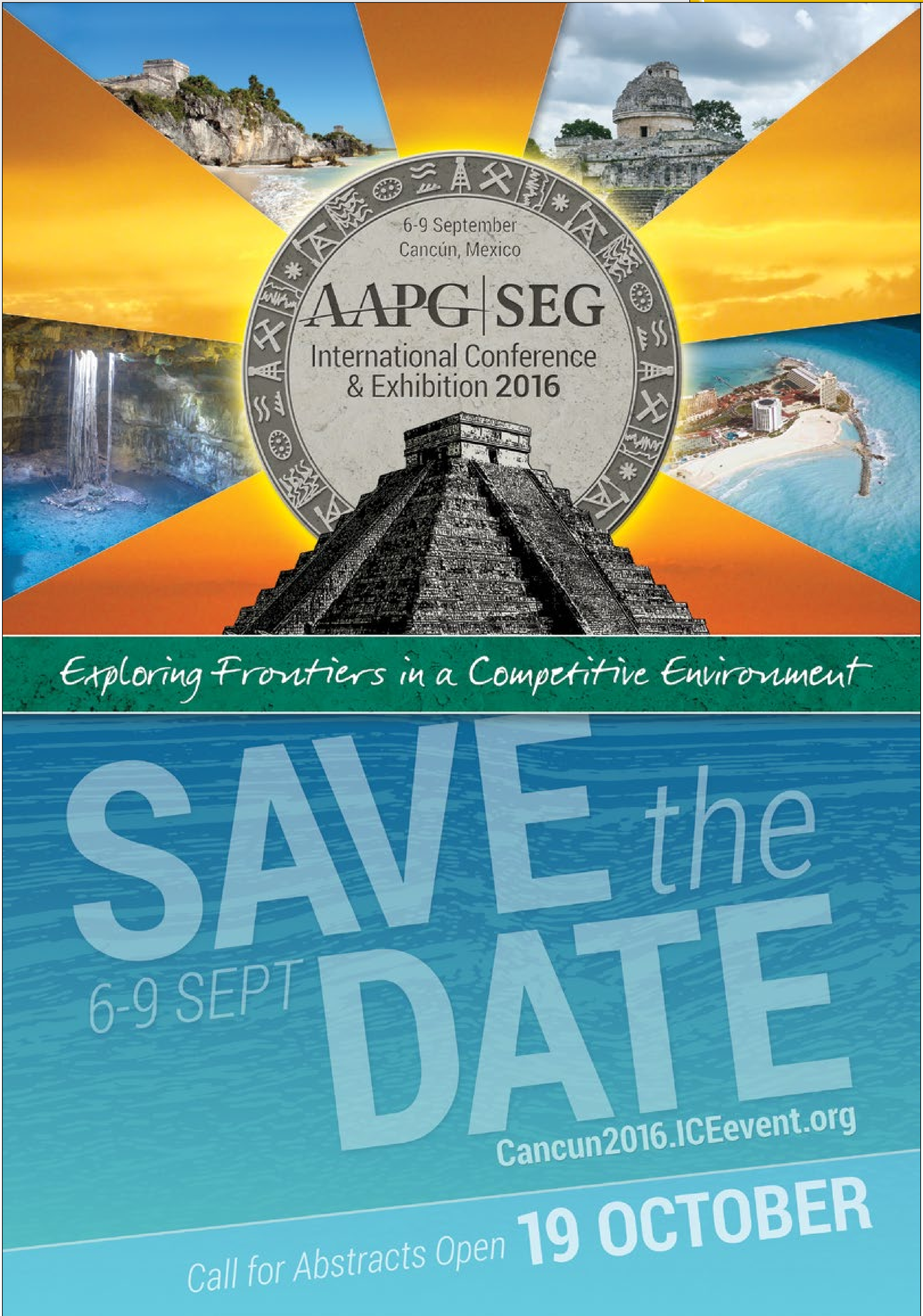
For Spectrum, the new position "facilitates unique volume deals with key clients, attracts more interest with global exploration super majors and provides unique opportunities to national oil companies who are seeking investments abroad," Eng said.

And the Spectrum CEO sees more expansion ahead.

"It is our goal to continue to expand its global reach and the volume of data that we can offer to our clients," he said. "We will continue to work with them to help them develop the next generation exploration hot spots." E



Overview of the North American portion of Fugro's multi-client library.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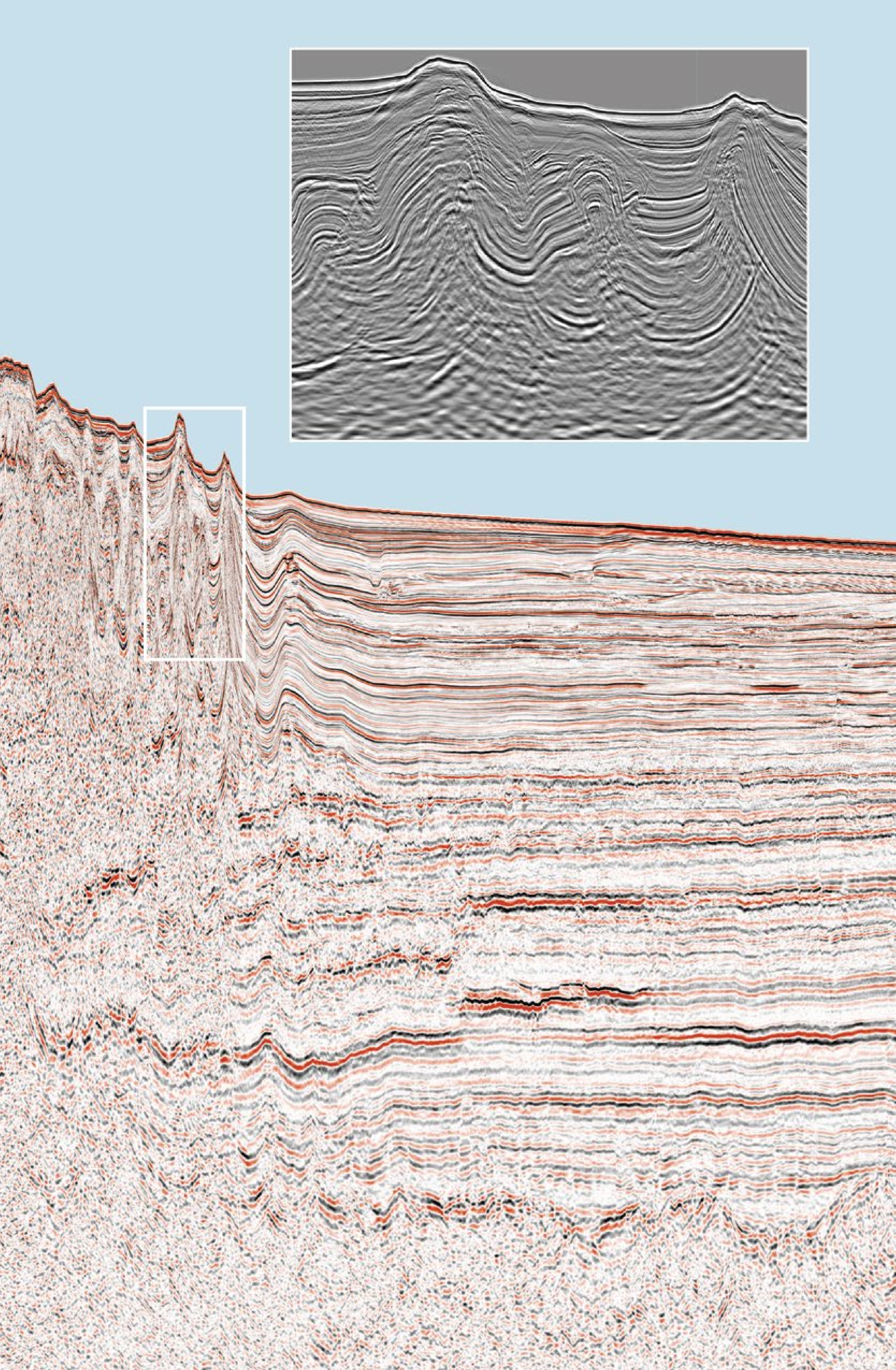

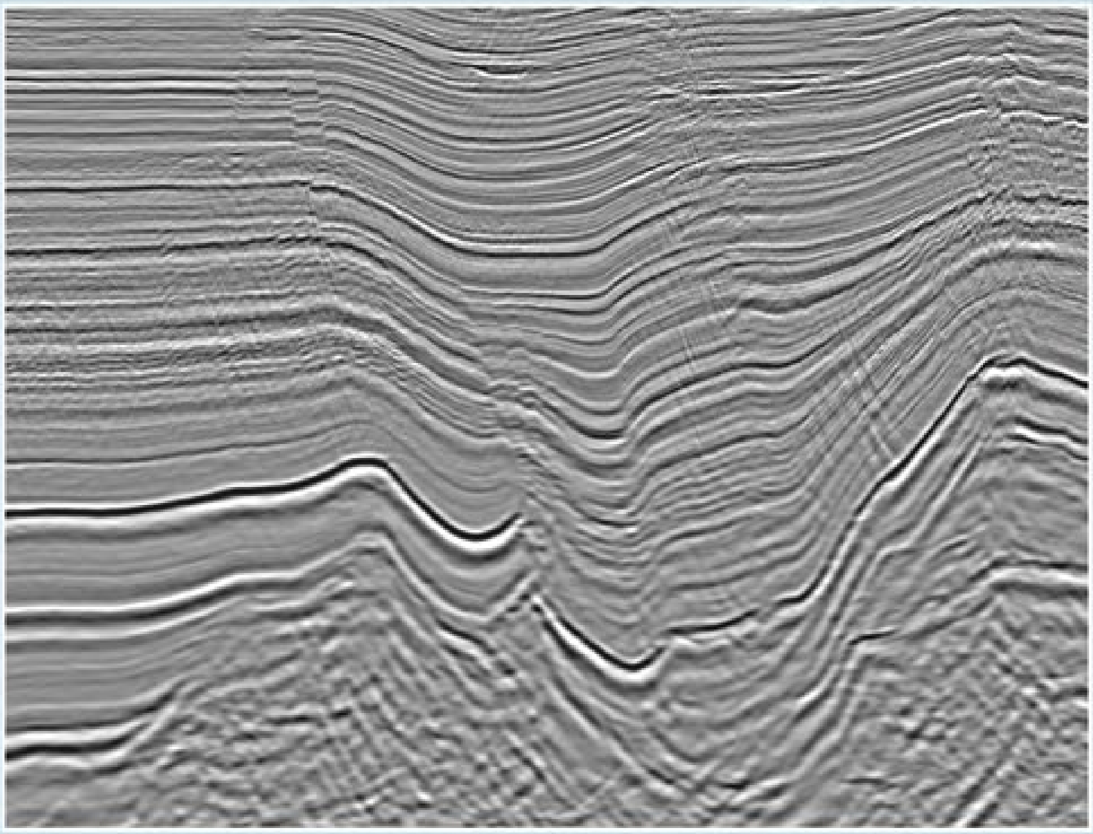

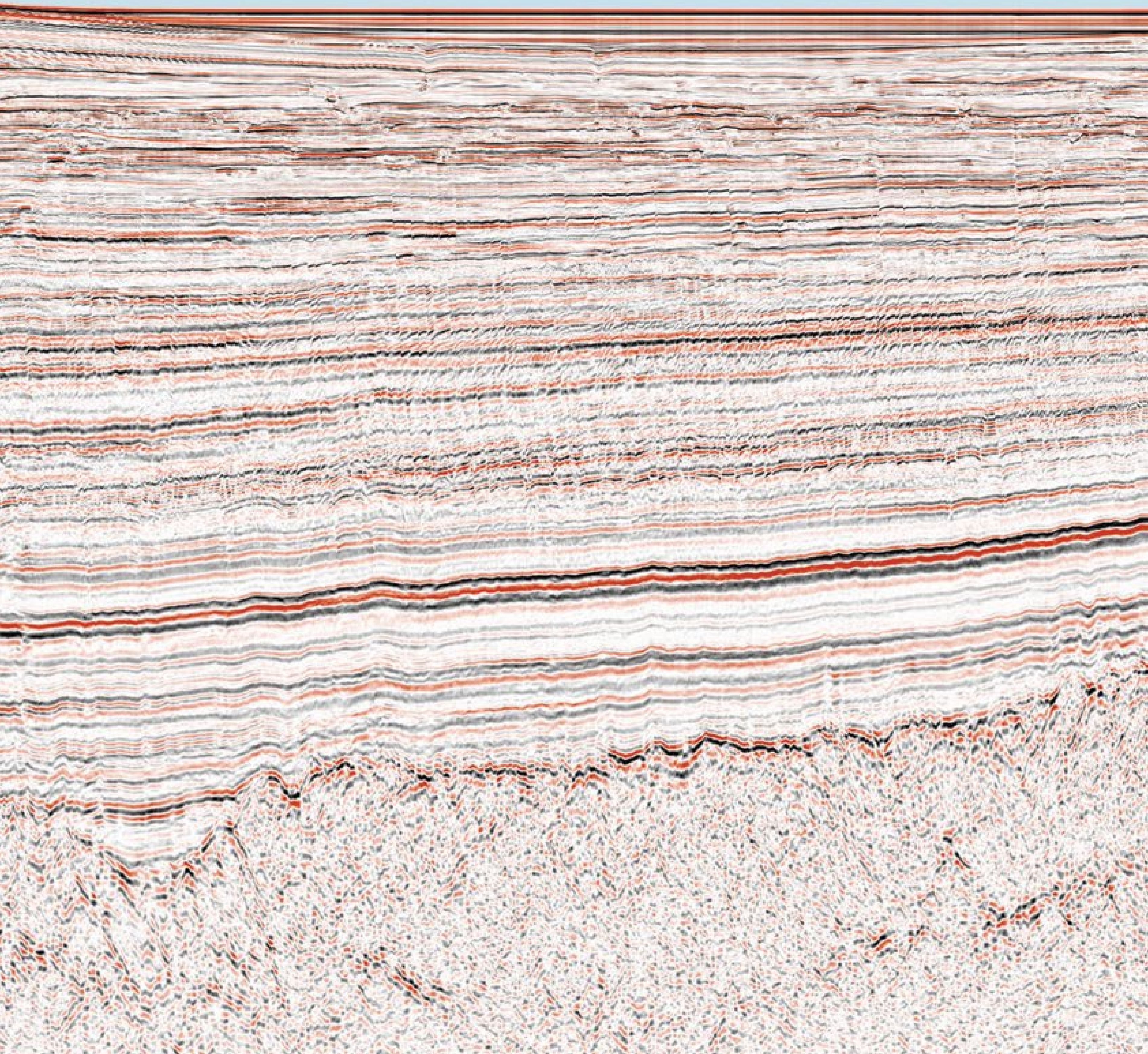

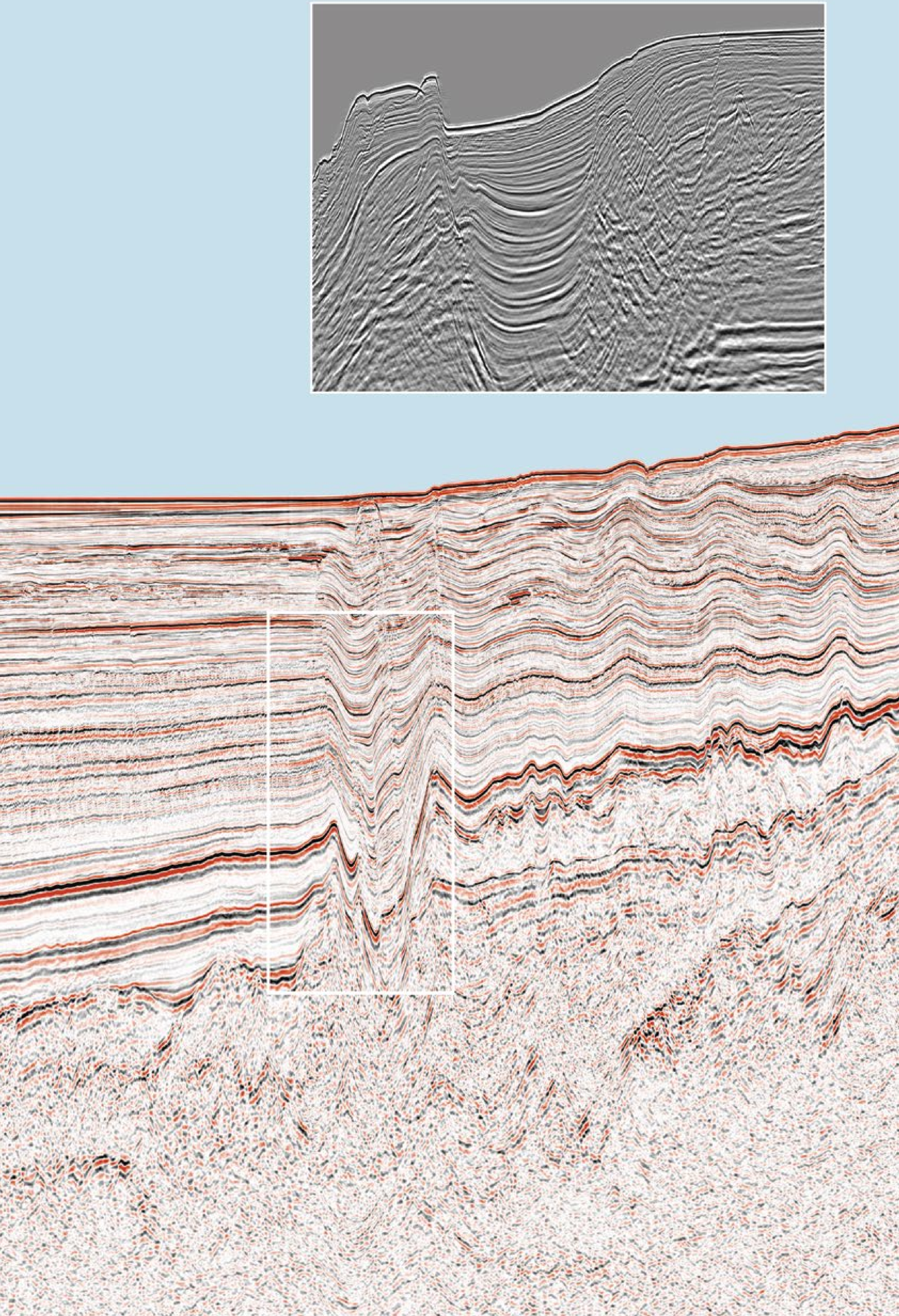


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Getting real about the Red Planet

A Down-to-Earth Approach to Mars Exploration

By BRIAN ERVIN, EXPLORER Assistant Managing Editor

All photos courtesy of NASA

NASA's Curiosity Mars rover recorded this view of the sun setting at the close of the mission's 956th Martian day (April 15, 2015) from the rover's location in Gale Crater. It illustrates just how alien an environment Mars would be for colonists from Earth.

The notion of terraforming and colonizing Mars has graduated from the realm of wildly imaginative science fiction into the realm of real-world possibility, but "possibility" and "practical reality" currently remain – literally – worlds apart.

In the August EXPLORER article, "How to Create a New Home of the Red Planet," AAPG Astrogeology Committee members Bruce Cutright and William Ambrose explained how the planet Mars could be terraformed into a new home for humanity, following the plan outlined by aerospace engineer Robert Zubrin and NASA planetary scientist Christopher McKay, which Ambrose and Cutright presented recently at the AAPG Annual Convention and Exhibition in Denver.

That plan involves crashing comets onto the surface, putting giant parabolic reflectors in orbit and pumping greenhouse gases into the sparse atmosphere of Mars – all in an effort to raise the temperature and atmospheric pressure to something closer to Earth's conditions.

But is that plan feasible with today's technology?

"Sort of the answer to your question is, 'Yes, *but* … '" Ambrose said.

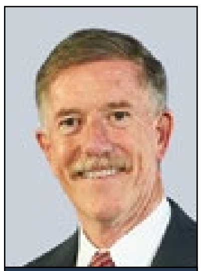
"We certainly understand how we could do it – the energy that it would take to find the right-sized comet and bring it into a grazing-type orbit, so the impact energy would be minimized," he said.

"The actual rocket engine to do that is under development," he continued. "Realistically, it would have to be something like the nuclear thermal rocket engines or the nuclear-electric rocket engines that have been tested, that we know we could build them if we had the will.

"So, the answer is, 'Certainly. We can do that.' We don't happen to have those engines sitting in a warehouse now, but we certainly have the plans and the capability of doing that," Ambrose added.

Getting Realistic

Obviously, turning Mars into a new Earth is still a few decades off – but so are slightly less ambitious goals, like those of the highly publicized and controversial non-profit organization Mars One, which aims to establish a permanent colony on Mars through a series of one-way trips by 2027.



REILLY

This is according to AAPG member James F. Reilly who, as a NASA astronaut with multiple shuttle missions and space walks under his belt, knows about the planning and preparation needed for such an undertaking.

Reilly also presented at the recent ACE in Denver.

Simply getting to Mars, he said, is a significant enough challenge in itself – and not just because of the practical limits of the available propulsion technology. We also lack the capability for the kind of indefinitely sustainable, self-contained artificial environment needed even to visit Mars, much less remain there.

"The current estimates are that we're going to have to recycle about 97 percent of everything we're going to be using and doing on the way there, while we're on the surface and, of course, coming back," Reilly said.

"And we don't really do that kind of recycling in any aspect of our lives here on the ground, or even in space for that matter," he added. "We actually have a fairly high consumable rate, even on the International Space Station."

There have been numerous experiments in self-contained environments, like the University of Arizona's Biosphere 2 and the Johnson Space Center's enclosed mission area, but none have been self-sustaining, Reilly explained.

"None of them have been really full up where you're growing your food, you're also growing the plants that will regenerate the oxygen in the environment for the crew, the completely enclosed water filtration systems that are going to be required," he said. "There are pieces of that, of course, in the International Space Station, but nowhere have we actually done end-to-end, full up, completely enclosed environments that would be the equivalent to what we would have to have in order to go to Mars."

There's also the psychological health of the astronauts to consider.

"Photosensitivity would be a big issue for folks," Reilly said.

"One of the misperceptions about Mars comes from the imagery we get back. If you were to look at, say, the Rover imagery, they've been not only color-balanced, but also given a brightness that would reflect what we would see here in daylight on the surface of the Earth. The actual fact of the matter is that Mars is only receiving half the solar energy, in terms of light, that we get here.

"So living on the surface of Mars would be very much like living in permanent twilight," he explained. "The brightest part of your day would be evening lighting that we would have here."

He also noted that anyone traveling to Mars would have to come to terms with the fact that they wouldn't hear the sound of rain, the sound of birds singing, or see green trees and grass for several long years, which would take more of a psychological toll than many might realize.

"You're going to be gone from home for somewhere around three years, and you've got to figure out how we're going to accomplish that ability to give them sort of the Star Trek 'holodeck' experience so that they can 'come home' at least for 30 minutes or so," said Reilly. "The things that you don't even think about, that we take for granted, are the things we would probably miss the most."

Running Start

Mars might be the next logical giant leap for mankind, but it's going to take quite a few smaller steps first to get a running start for that leap.

"We're not quite there yet. We're working on it. In fact, a number of major projects on the International Space Station are to look at how we would actually get there and survive," Reilly said.

In addition, he said work continues on Earth toward creating the self-contained,

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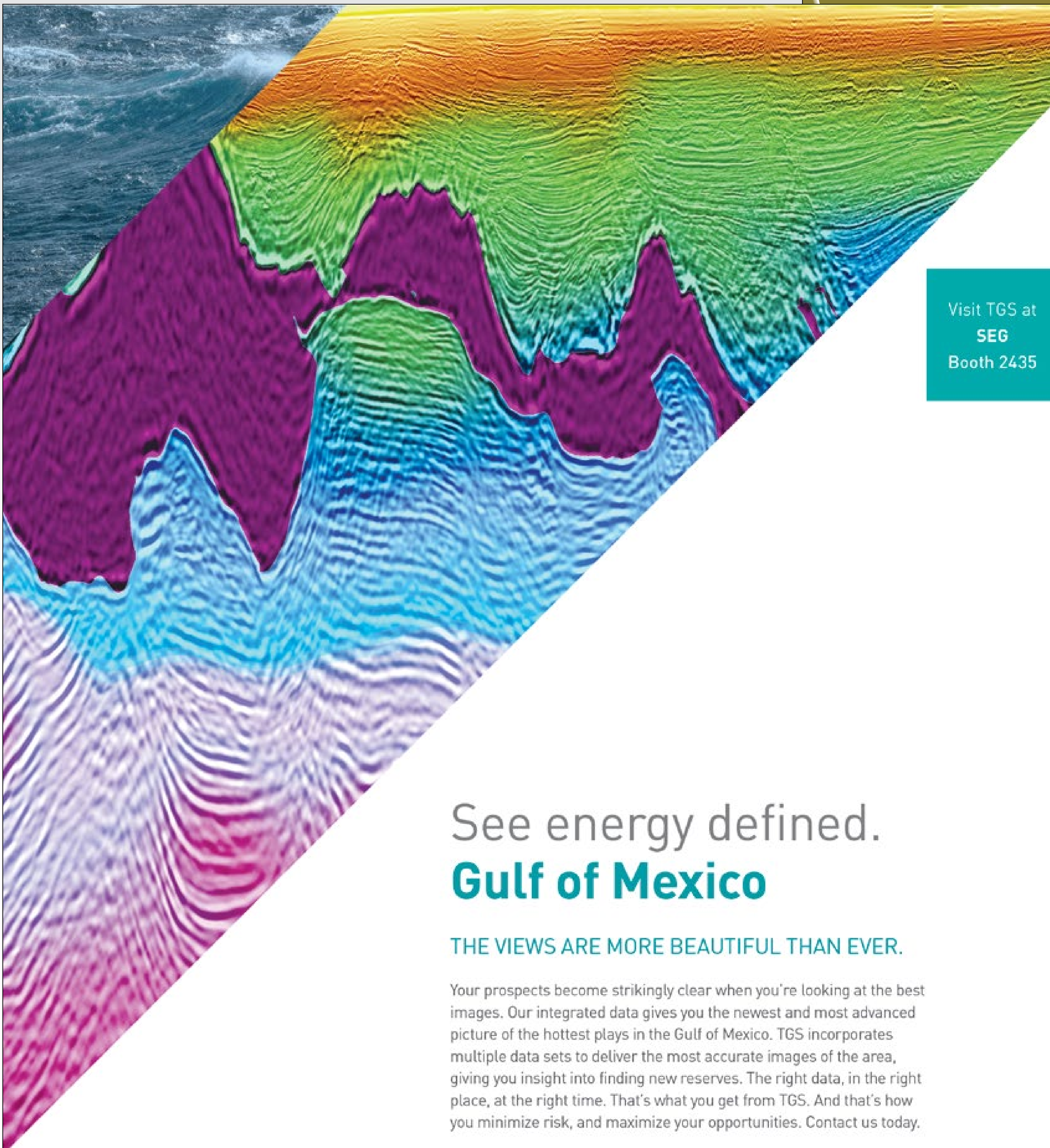
An elongated crater called "Spirit of St. Louis," with a rock spire in it, dominates this scene from the panoramic camera (Pancam) on NASA's Mars Exploration Rover Opportunity. In this version of the image, the landscape is presented in false color to make differences in surface materials more easily visible.



Practice

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self-sustaining environments needed to colonize Mars.

"Let's pursue that. If you want to pursue a Mars One-type objective, let's see if we can make that work for that period of time here on the ground," he said.

Also, along with being a worthwhile object of exploration for its own sake, Earth's moon makes for a pretty good "practice Mars," if we can muster the public interest to return.

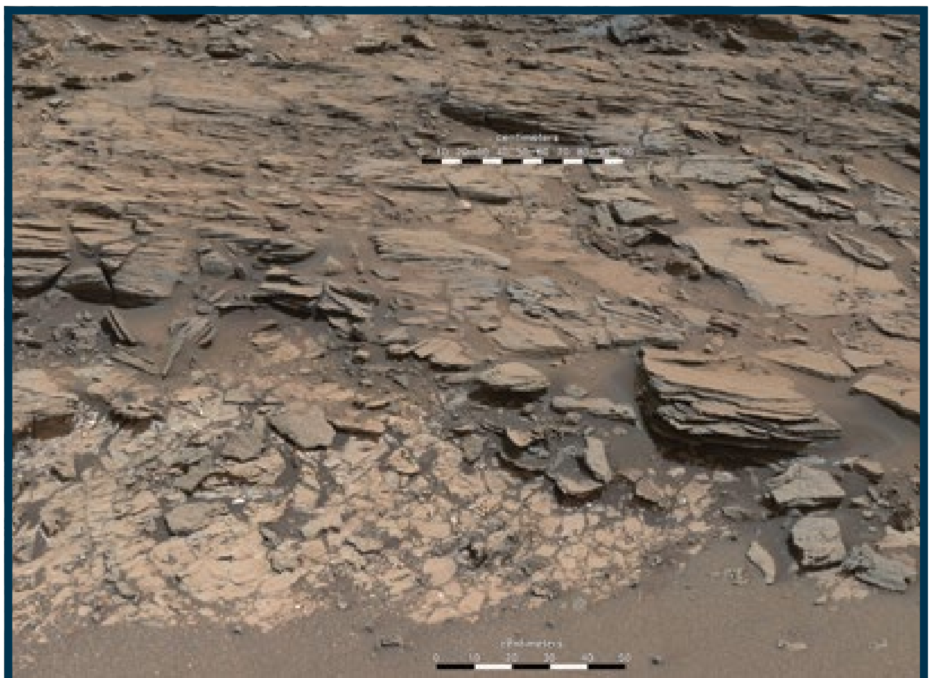
"The moon is the perfect laboratory for that, particularly looking at the ability to put people in a completely enclosed and regenerable environment but have them close enough so that if you have a crop failure or something unforeseen happens, you're only two or three days away from getting them spare parts, or if the absolute worst happens, getting back home," Reilly said.

His hope and expectation is that lunar exploration in the next few years – and Martian exploration in the next 50 – will begin to see a model similar to that of Antarctica, which has had a permanent research presence since the 1940s, cycling teams in and out in four- to six-month increments.

"When it comes to putting a permanent human presence on the surface," Reilly said, "I think that under the current spending profiles that people seem to be looking at, we're 30-50 years out."

A New World

And if 30-50 years seems like a long time, consider this: That's the *fast-track*, and even that will be possible only if the



This view from the mast camera on NASA's Curiosity Mars rover shows a site where two different types of bedrock meet on lower Mount Sharp.

AMBROSE

CUTRIGHT

decision-makers, and the people who vote for them, have the will to do it.

"The benefits are somewhat diffuse," Reilly said. "In other words, it's hard to advertise 'this is what it's going to be worth to society in the future.'

"Of course, it's paid for itself many times over in all the things we have done up to this point in space exploration," he continued, "but it's hard to recognize that on the front end, so governments have to go to the populace to fund the projects."

However, if we can clear the technological hurdles necessary to get humans to Mars, the benefits will go far beyond having a new planet to inhabit.

It would help to renew the planet we already have.

For instance, if scientists and engineers can crack the code on self-contained, sustainable artificial environments to serve as interplanetary and Martian habitats, Reilly said, "there'll be literally hundreds of spinoffs and benefits that can be used here on the ground."

"The spinoffs that everybody talks about from the Apollo program – the computer systems every one of us uses now, the life-support and human health technology and health monitoring that came out of the Apollo program – those are the things that have benefited everyone, not just the astronauts that have to go to the moon," Ambrose added. "(AAPG Honorary member) Harrison Schmitt's discovery of helium-3 and quantification of titanium and other resources on the moon – that doesn't just stand as an independent discovery. That stands as a huge reservoir of energy that we, the human species, will be able to exploit in the future through helium-3 deuterium fusion reactions."

The benefits would be inestimable, while the price of not doing it would be calamitous for the human race.

"What if we choose not to explore? What if we as geologists and engineers choose not to explore?" Cutright asked. "It's a failure of nerve were we to choose not to do that, and it comes back to the most basic every day life of every human: Shall we choose to have a declining standard of living? Shall we choose to have a declining quality of life? Because that's what the choice is.

"We wax philosophical, but these are truly, very much at-home practical questions that we as members of AAPG need to talk about and need to promote," he added. "All people aren't going to resonate with the idea of going to terraform Mars, but when you bring it back to 'Shall we choose not to improve our quality of life? Shall we choose not to educate our children?' Those are the choices that really underlie this whole idea of choosing to expand and prosper as a species." E

How the Jusepin Deep Field Was Discovered – And Lost

By BOB ERLICH

The discovery and untimely loss of the Jusepin Deep Field in Venezuela is a story of creativity, perseverance, technical excellence and emotion – which are qualities we as geoscientists like to feel we bring to our jobs every day.

As with any such story, a technical description of the process of how this discovery was made would involve details like how the seismic data was eventually processed to reveal a previously unseen structure, or how structural geologic analysis was utilized to build a seamless, risk-reducing model.

If the story focused only on the technical work, though, the personal aspects would be left out; specifically, the sense of accomplishment and satisfaction that comes from getting the geology right and of validating one's technical capabilities in real time.

With that in mind here's an acount of how the dedication of the Total Venezuela and Amoco Venezuela technical teams paid off, and how they got the geology and geophysics right to find a major oil field when no one else believed it existed.

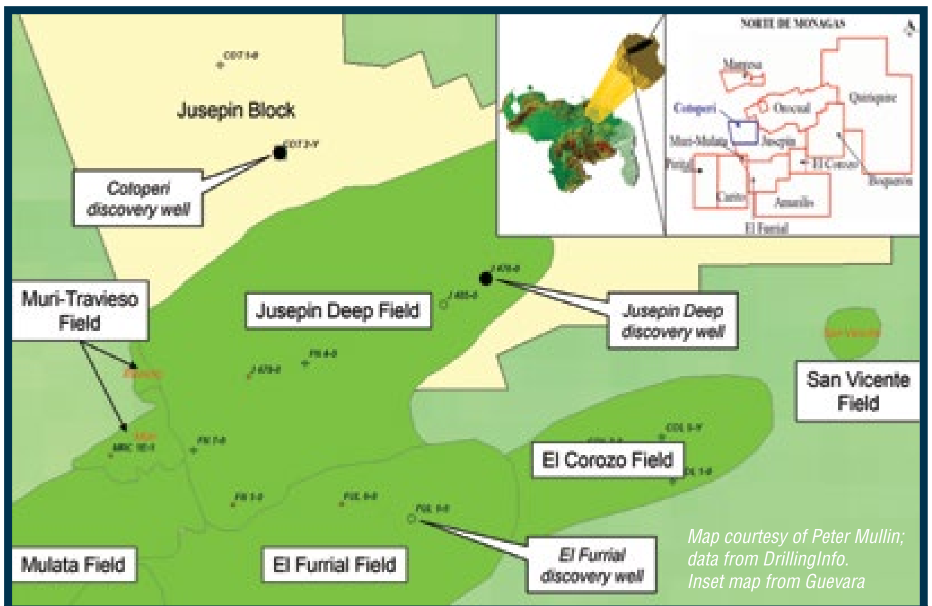
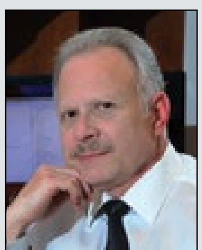


Figure 1 – Jusepin Block, discovery wells, and surrounding fields.



ERLICH

AAPG member Bob Erlich is president and CEO of PanAtlantic Exploration. He's held a number of senior technical and executive positions during his more than three decade career with major multi-national and small independent oil and gas companies such as Amoco, Burlington Resources, BP, Petrolifera and Hess. His assignments included work in Trinidad, Peru, Colombia, Venezuela, Argentina, Suriname, Brazil, Costa Rica, Panama, Guatemala, Equatorial Guinea, the United Kingdom and the People's Republic of China.

Gradual Progress

The groundbreaking discovery of the super-giant El Furrial Field in 1986 prompted the entire oil industry to vie for the chance to become involved in this new play. Many companies tried to position themselves with Petroleos de Venezuela (PDVSA) to become the "partner of choice," and offered to work with the PDVSA affiliates on various technical service agreements.

Joint PDVSA-IOC projects focused on various problems considered critical by PDVSA's technical leadership, such as depth processing of seismic data, sequence stratigraphy and biostratigraphy.

Amoco was no exception, and through personal and business contacts gradually began to develop a relationship with El Furrial operator Lagoven in the field of seismic depth imaging and processing.

At the same time, Total had established a similar relationship with Lagoven, and was already working on joint projects in the El Furrial play area (figure 1).

In that highly competitive atmosphere prior to "La Apertura" ("The Opening" of the Venezuelan oil industry to private investment), I became a charter member of the new Amoco Venezuela and in early 1989 took part in some of the first meetings and work sessions with Lagoven in Caracas. That initial team included Bob Marksteiner and the late Nelson Briceño, who presented Amoco's depth seismic interpretation of the Furrial-1 drill line, Wendy Hale-Erlich, Steve Barrett and myself.

We all saw that meeting as a test of Amoco's technical capabilities and knowledge base.

The primary focus of that first project was to see how well Amoco could model lateral velocity variations within the Carapita Formation, and by all accounts the work was well received. Steve and I also presented some work we had done on regional tectonics and stratigraphic correlations between Venezuela and Trinidad.

All of our efforts were focused on technical problems that had direct relevance to the Furrial play. Following the meeting our Lagoven counterparts led a joint field program in eastern Venezuela, during which the "Lagovitos" made a point of wearing their Total baseball caps in the field (figure 2). It was their way of sending a clear and not too subtle message that we were not the only company trying to make an impression.

By 1990 our efforts had begun to pay off. Amoco Venezuela had positioned itself well with senior PDVSA management to take part in an expanded set of technical cooperation agreements with the various affiliate companies (Lagoven, Corpoven and Maraven).

At that point, Amoco Venezuela formally consisted of me (geoscience), Jon Blickwede (geoscience), Roger Neal (engineering) and Alex Weisselberg (negotiations). Our expanded set of projects very quickly led to a staff increase that included several permanent and consulting members, including Antenor Aleman, Ralph Baker, Ron Nelson, Bob Marksteiner, the late George Kronman, and the late Aldo Boccardo, who was a very well respected Venezuelan geologist and longtime PDVSA employee.

We began joint field studies with Lagoven and Maraven in eastern and western Venezuela, respectively, and by 1991 we believed we were ready for the first licensing round.

The first marginal fields bid round was announced in 1992 (figure 3) and several of us spent two weeks at the Hotel Tamanaco in Caracas going through the PDVSA data rooms. Unfortunately, the blocks appeared to have little upside and were commercially unattractive, so we did not recommend bidding at the time.

All our efforts and work seemed to fizzle out in an instant, and at first it looked like Amoco would fail in Venezuela.

The "Risk Police" and an Anchor Point

Fortunately for us, and for the international industry in general, the first marginal fields bid round was widely considered to have been a failure, as only two contracts were signed. The lack of prospectivity in the assets being offered by PDVSA and restriction of the contractors to currently producing horizons was insufficient incentive for foreign operators to take the financial risk.

PDVSA then decided to immediately launch the second marginal fields bid round, which took place in March 1993 (see figure 3). Again, Amoco Venezuela did not bid, even though this time the technical team recommended bids on several blocks.

Despite of our no-bid status, Amoco Venezuela underwent another growth spurt. During that period from late 1991 to early 1994 Amoco re-opened an office in Caracas and the Houston/Caracas-based teams expanded to include 21 professionals.

By the time we began preparations for the Second Marginal Fields bid round we finally had the organizational capability to handle the demands of the bid rounds and our multiple technical cooperation agreements. Although our staff and activities in the country increased, there were no guarantees we would find a successful "anchor project," and my future in eastern Venezuela was also about to change.

For some time I had been trying to convince Hans Krause (Intevep's E&P manager) to approve joint study proposals on various geologic problems of mutual interest. His response, regardless of the proposal, was that the work already had been done during the BP-PDVSA countrywide sequence stratigraphic study.

After nearly two years of having my proposals turned down, I decided that Amoco should move forward on its own, so I left my position in eastern Venezuela to work on those projects in exclusively western Venezuela.

My exit from eastern Venezuela meant that I would not directly participate in what would become the most important event for Amoco in Venezuela. One of the three blocks we really liked in the second bid round was the Jusepin Block (figure 1) – not for the old shallow field production, but for the deep potential. The existing 2-D seismic suggested that a large, Furrial-type thrust anticline might be present under the existing shallow field (figure 4).

When Total captured the block we were very disappointed but not completely surprised, knowing Total had been working on the play with Lagoven since at least 1989.

Jean-Paul Barbot, at that time lead exploration geologist for Total in Venezuela, had seen the potential for a new undrilled structure at depth and pushed his management to bid on the block. Jean-Paul recently described to me how this happened:

"*The Jusepin block attracted my attention because I had worked previously on the blocks to the south with the famous El Furrial discoveries. Looking at the data provided by PDVSA I had the impression that another fold could be present north of El Furrial within (the) Jusepin block. Of course it was not very easy to see and was more interpretative than being able to spot it on the poor seismic dataset. Especially since the seismic lines had*

Figure 2 – Amoco-Lagoven joint field team in Eastern Venezuela, 1989. Front: Wendy Hale-Erlich (left) and the late Berta Contreras; standing, from left: Rolf Juerges, Steve Barrett, Eduardo Alvarez and the late Marco Odehnal.

See **Risk Police**, page 36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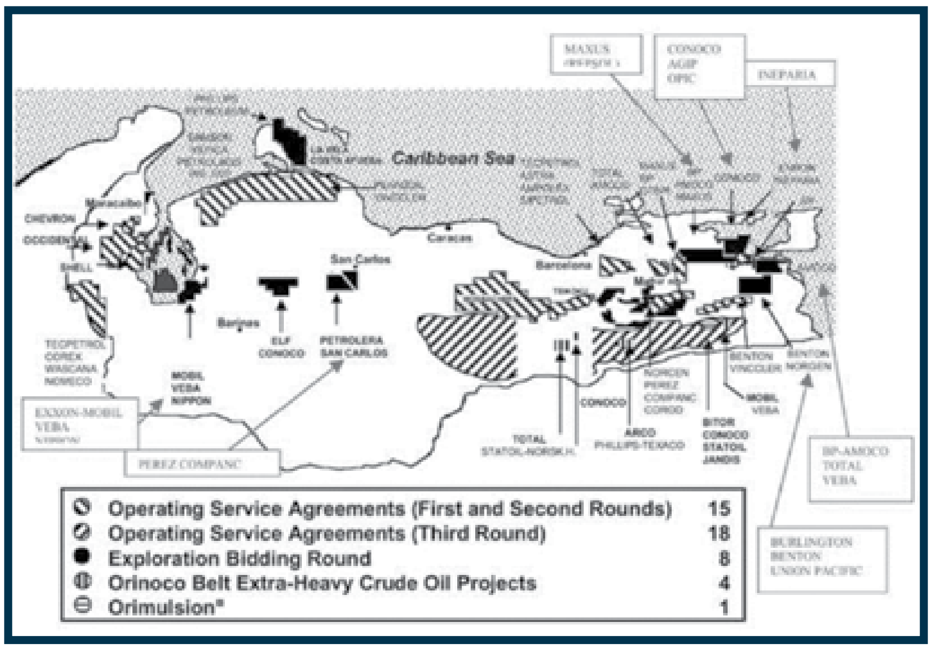

Risk Police

from page 34

been acquired in different vintages with different orientations and crossings in the southern part of the block where I suspected the undrilled fold could be."

"Total took (the) Jusepin block in this round with a two-fold commitment: first, a small redevelopment project for the Nodosaria turbiditic sands (we did not want to touch the old La Pica Field, which has too many wells and looked rather dangerous), and second, an exploration program with reprocessing, new 2-D acquisition and two wells. So, far as I remember our proposal was not the highest in economical terms but was judged more adequate and technically better by PDVSA so that we finally won the block."

"Total decided then to farm out part of its interest and I was asked to organize that too. We contacted at the beginning only three companies and Amoco was one of them. I remember that I went to Houston to present the block to Amoco, to Roger Sels and a woman geophysicist (Ann Nevero). They seemed to like it and Amoco made a very quick offer to Total. I had a big fight with my management because I wanted to retain at least 60 percent to keep the majority but I lost this fight and Amoco took 45-50 percent."

As I told Jean-Paul after the fact, I was elated that he'd lost that fight with his management!

I recall that Roger Sels, Ann Nevero and Ron Nelson led the recommendation to the Prospect Quality Team (PQT), which was headed at the time by Tony Benson and known affectionately as the "Risk Police."

Being cognizant that Total, BP and Triton had only just discovered the super-giant Cusiana field in a similar geologic setting (albeit in Colombia), the PQT approved the recommendation to enter the block and Amoco finally had its "anchor point" in Venezuela.

The two companies worked together on the technical program, which consisted of reprocessing the existing 2-D seismic and the acquisition of new 2-D. By early 1995 the deeper target was adequately imaged and it was time to recommend a well.

A "Leap of Faith"

Roger Sels led the technical team back to the PQT, now run by Peter Carragher with Gary Citron contributing, for the final review. As Roger tells it:

"Probably the two key indicators of a prospective structure between El Furrial and Orocual were: a dry hole in the Carapita above Jusepin Deep where our stratigraphic correlations indicated a possible structural high (this well had a Naricual objective but never got there due to drilling problems); completion of dip oriented, balanced cross sections and a tie of strike-oriented sections showing a viable structural geometry between the two mega-structures."

Jean-Paul was asked to return to Houston to participate in the PQT review; having an "outsider" participate in Amoco's internal risk process was not something I had ever seen before, but it paid off. Peter Carragher later told me that he and Gary felt that trap definition/structural closure in a strike direction was the key risk, as could be imagined in such a complex area.

That first well, J-476X as it was known (figure 4), was then approved by Worldwide Exploration Vice President Scott Urban, and a spud date of September 1995 was finalized.

We didn't have long to wait for an answer as to whether or not our "leap of faith" was successful. In early February 1996 the J-476X reached a total depth of 5,620 meters (18,437 feet) and tested 14,200 bopd of 33-35 degree API oil from two zones in the Naricual.

It was a resounding success and everyone associated with the project and the team felt great. Management again began to staff up and Amoco filled out the Houston and Caracas technical teams as we awaited yet another marginal fields bid round (number three).

Later that September the appraisal well, J-479X, successfully appraised the Jusepin Deep structure and tested 8,050 bopd. For the remaining initial members of the team – Alex Weisselberg, Roger Neal

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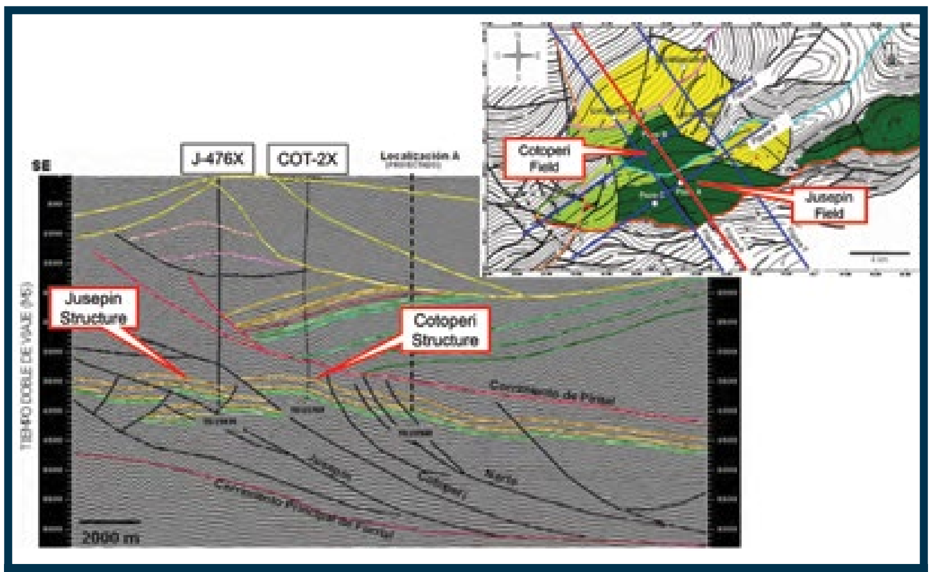

Figure 4 – Structure map and interpreted seismic line over the Jusepin and Cotoperi Fields showing the J-476X and COT-2X discovery wells (Villamizar, 2011); see fgure 3 for base map.

Vindication

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and I – it was a vindication of our belief in the original mission and our faith in the process.

The celebration was brief, since much work still needed to be done before the field could be considered a commercial success.

By May 1997, the field was producing 10,000 bopd and 25 mmcfpd but ramped up to 18,000 bopd by October.

The expectation was to increase production to 30,000 bopd by the second quarter of 1998 as new wells were tied into the facilities but by September the field had exceeded that milestone and was producing 35,000 bopd.

Unfortunately, by then Amoco had suffered a setback to its aspirations in the country when the company failed to win a single block in the third marginal fields bid round (late 1997). This failure had far-reaching implications, as large staff increases in Houston and Caracas had been based on the false notion that "Of course we would win at least one block!"

Unless we achieved success in our new exploration blocks (Guarapiche and Punta Pescador), we knew that our future in Venezuela was at risk.

An Ignominious End

Although the news outside of Jusepin was not encouraging for Amoco, success in the Jusepin Block continued in 1998 as a new structure, Cotoperi (figure 4), was confirmed productive. The Cotoperi-2X tested 34-degree API oil at a rate of 7,650 bopd and everything seemed to be working as planned.

Unfortunately, in August 1998 and after a string of successes and spectacular growth, the Venezuela team was stunned by the announcement that BP would acquire Amoco in a then unimaginable all-stock deal worth $48.2 billion. We quickly realized that the "merger" would decimate the Amoco Venezuela team, as BP already had its own teams working in Caracas.

The announcement was preceded by the news that the Guarapiche-1X well would be plugged and abandoned, and was followed in short order by the failure of the Morocoto-1X well to find commercial hydrocarbons (it found gas), thus condemning our exploration blocks.

The rest, as they say, is history.

By the end of January 1999, most of the Amoco Venezuela team had left the company and those who remained were absorbed into BP Venezuela's operations. The election of Hugo Chavez as Venezuela's next president and his subsequent purge of existing senior management within PDVSA following the strikes in 2002 made it clear that the country would take a big step backward, and away from its former goals of boosting production and increasing foreign investment in the hydrocarbons sector.

Foreign operators scaled back their investments accordingly as talk of delinquent tax payments, royalty increases and compulsory strategic associations were communicated from Caracas. The foreign operators were soon told that they would either accept the new strategic associations, in which PDVSA had majority ownership and control of the assets, or be expropriated.

Total and other operators resisted as long as possible, but in April 2006, Jusepin Deep was seized by the government, effectively ending independent operations for the partners. A year later Total and BP agreed to split proportionally a $250 million "compensation payment" from the government, a sum that was far below the estimated $1 billion asset value the reserves were worth at the time.

This ignominious end to the Jusepin Deep story only represented an end as far as Total and BP (Amoco) were concerned. At the time of the "sale" the field was producing 35,000 bopd and is still producing 6,000 bopd from nine wells as best I can determine. It likely will continue producing for some years to come.

However, regardless of how the story ended, the achievements of the people who conceived of and led the discovery of this major oil field in eastern Venezuela cannot be diminished. To them I say bravo team; you did well. E


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The Geophysical Corner is a regular column in the EXPLORER, edited by AAPG member Satinder Chopra, chief geophysicist for Arcis Seismic Solutions, Calgary, Canada, and a past AAPG-SEG Joint Distinguished Lecturer. This month's column deals with the determination of brittleness in shale formations.

Determining Brittleness From Seismic Data

By SATINDER CHOPRA and RITESH KUMAR SHARMA

The key elements for shale resource evaluation are the mineral content – such as clay, quartz and calcite – the total organic carbon (TOC) content, the brittleness and some mechanical properties of the shale rocks. Geomechanical studies are necessary both for understanding wellbore environment stability and also interpreting well log data, by estimating the mechanical properties of the subsurface.

Simply stated, an accurate geomechanical model needs to be conceived, and its main features are the three principal elements – stresses, pore pressure and the rock strength. Availability of these parameters define a good geomechanical model, which help with the evaluation of wellbore stability, fracture permeability, drilling direction and others.

Highly brittle shale formations fracture better, and thus provide more fracture pathways for release of the hydrocarbons. The shale's mineral content can be determined from the XRD analysis, or estimated from the wireline well log curves.

Similarly, brittleness and TOC can be estimated from the well log data – but this information is only available at the location of the wells.

* * *

In this article we focus on determination of brittleness of shale formations from seismic data – and demonstrate that brittleness is a relative term that has no standardization and needs to be carefully calibrated with the relevant data before it is used for interpretation.

Before we go ahead with that description, some common definitions of terms and elastic constants used in the discussion on brittleness are discussed first.

▸ When a slab of rock is acted upon by a force, it is expected to undergo a change in its dimensions.

For simplicity, let us consider the change along the length of the slab.

The force acting on a unit area of the rock is referred to as **stress**, and is commonly measured in Pascals (Pa) or pounds per square inch (psi). The resultant change in length of the rock or the rock's deformation in response to the stress is measured as the change in length per unit length, and is called **strain**.

Being a ratio of two lengths, strain has no units.

Strain may be of three types, depending upon the change produced in the rock on the application of stress:

✓ **Longitudinal strain** is the change in length per unit length.

✓ **Volumetric strain** is the change in volume per unit volume.

✓ **Shearing strain** is the angle through which a face of the rock sample perpendicular to the fixed face is turned.

As a result of the tectonic activities that Earth experiences, subsurface rocks undergo two types of stresses – the stretching or extensional types of stresses, (or tensile stresses, implying the rock is under tension), and the compressive stresses.

The strains corresponding to these two types of stresses are referred to as **tensile** and **compressive** strains respectively.

▸ When the strain produced in a slab of rock is plotted against the applied stress, the graph shown is straight line, implying stress is proportional to strain – a result known as **Hooke's law**. The gradient of the straight line is referred to as **Young's modulus**, usually denoted as E.

Young's modulus is a constant for a given material and is a measure of its stiffness. It is measured in Pascals (Pa) or pounds per square inch (psi). For the rocks that we commonly deal with, E turns out to be a large number, and thus larger units such as Mega Pascals (MPa) or Mega psi are commonly used.

Similarly, depending on the two other types of strain, we talk of two other moduli of elasticity – namely **bulk modulus** (κ), which corresponds to volume strain and is a measure of the rock's incompressibilty, and **shear modulus** (μ), which corresponds to shearing strain and is a measure of the rock's rigidity.


CHOPRA


SHARMA

Besides these, there is another elastic constant, (λ), that is commonly employed in rock physics and is related to the bulk modulus. For this reason it is considered a proxy for incompressibility of the rock samples.

Both λ and μ are also known as **Lame's constants**, named after the French mathematician, Gabriel Lamé.

▸ When a slab or rock is compressed in one direction, it tends to expand in the other two directions, perpendicular to the direction of compression. The ratio of the fractional expansion to the fractional compression of a rock is referred to as **Poisson's ratio** (ν) – it is a measure of the rock's strength, and its values for most rock types range from 0 to 0.5.

Thus there are different elastic constants (E, ν, κ, μ, λ) that are used for characterizing reservoirs. Knowledge of any two of them allows the computation of the others.

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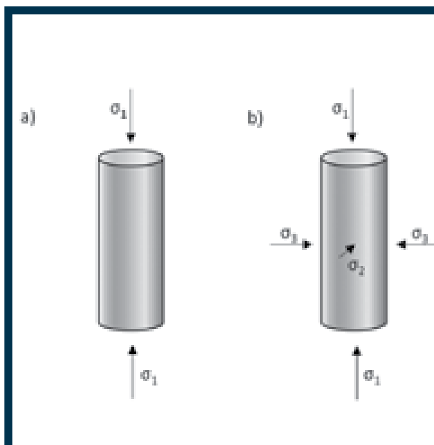
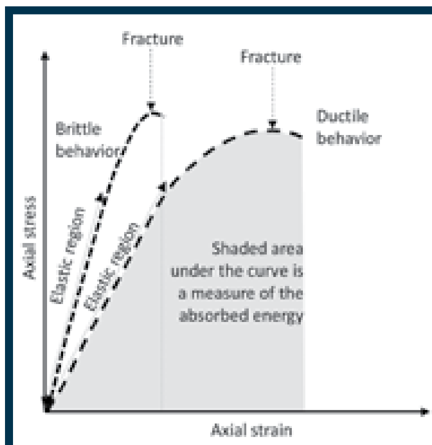


Figure 1 – Schematic showing application of (a) uniaxial, and (b) triaxial on rock samples.



Brittle versus ductile behavior of rock samples as seen on a stress-strain graph.

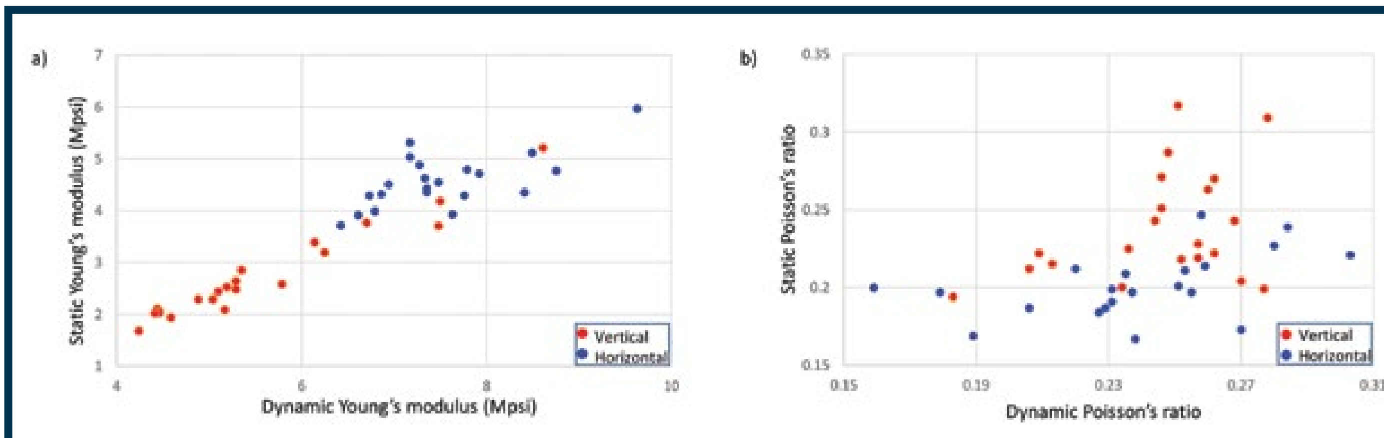


Figure 3 – (a) Static Young's modulus (YM) values plotted against dynamic YM values. (b) Static Poisson's ratio (PR) values plotted against dynamic PR values. The values were derived from vertical and horizontal measurements on Baxter shale core samples and reported in SPE 115736 by Higgins et al. (2008). We notice that the horizontal static and dynamic YM are greater than the YM values in the vertical direction. The static and dynamic Poisson's ratio (PR) measure in the horizontal direction are lower than the PR values measured in the vertical direction. Also, there is a well-defined relationship between the static and dynamic YM values, but not so between the static and dynamic PR values.

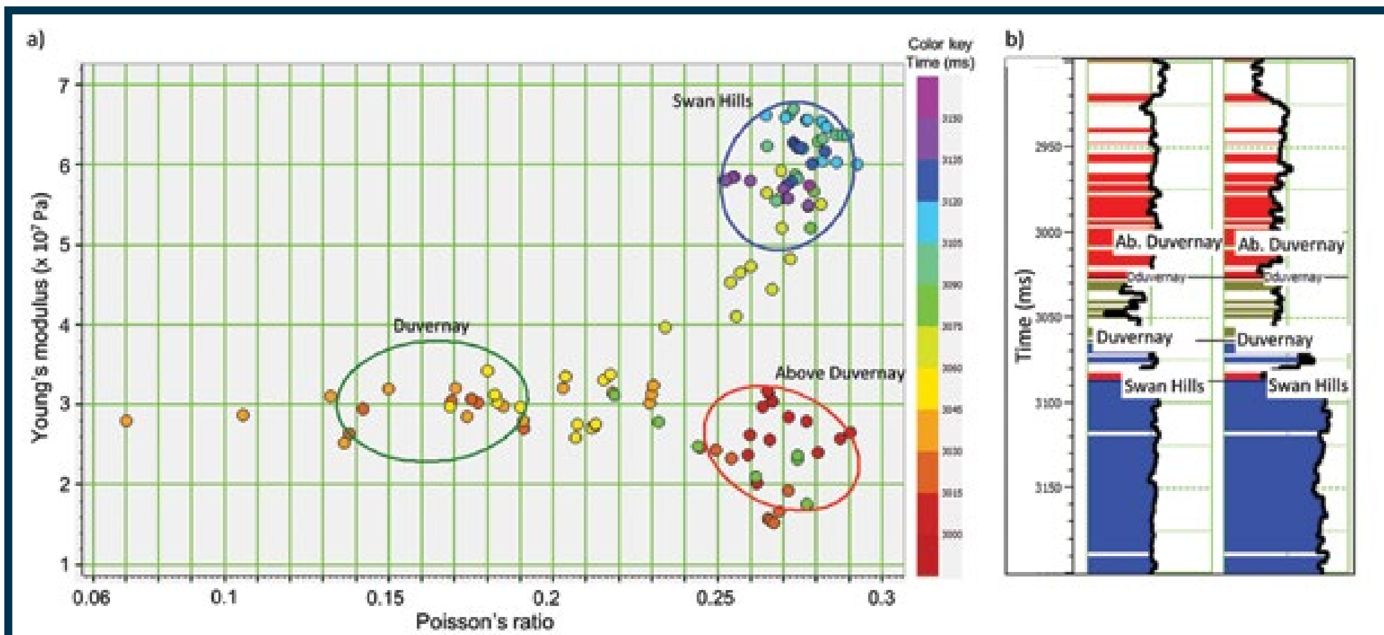


Figure 4 – (a) Crossplot between Poisson's ration and Young's modulus attributes for a zone selected to cover the Duvernay, Above Duvernay and Swan Hills intervals on the log curves. Separate clusters of points are seen on the crossplot. Three clusters are enclosed with polygons and the enclosed points are projected back on to the log curves as shown in (b). The polygons highlight the zones as marked on the crossplot.

Continued from previous page

* * *

The values of these constants are usually determined in the laboratory by making two distinct types of measurements on rock samples.

▶ The first types of measurements are those wherein the rock samples are loaded with known stress magnitudes and the resulting strain amplitudes are measured.

A typical application of stress on a core sample of the subsurface rock – and studying how it fails – is called the **uniaxial compressive test**, where the two other stresses are zero (figure 1a). Such a test yields the rock's **unconfined compressive strength** and can easily give away along the planes of weakness in the core sample.

A more preferred test is the **triaxial compressive test** (figure 1b), wherein confining stress is applied on the core sample, and then the axial stress is applied until it fails. While performing such tests, the axial strain is noted as a function of axial stress and the two are then plotted.

Figure 2 shows such a tensile stress-strain curve.

As mentioned above, Hooke's law relates the applied stress to the resultant strain and postulates that this relationship is linear. The slope of the linear or straight-line stress-strain curve yields the Young's modulus. The temporary change in shape of the rock samples under applied stress such that it regains its original position once the stress is removed, is referred to as **elastic deformation**.

However, as the applied stress is continuously increased, the elastic limit of the rock sample is crossed, so that the straight line deviates into a curved segment exhibiting **plastic deformation**, i.e. rocks undergo permanent deformation when the applied stress is removed. The curved segment on the stress-strain plot shows that the rock sample does not immediately regain its original position and needs more time. This is referred to as **viscoelastic** behavior of the rock sample.

If the rock sample is subjected to more stress loading, it could reach its failure limit, when the rock sample could get ruptured.

Depending on their characteristics, rocks are normally classified as either **brittle** or **ductile**. These two can be differentiated based on the amount of plastic deformation that the rock undergoes before fracture occurs.

Figure 2 illustrates that extensive plastic deformation occurs in the ductile rocks prior to fracture, while brittle rocks show little or no plastic deformation before fracture.

As the area under the curves is a measure of the absorbed energy it can be stated that ductile rocks absorb very much energy before getting fractured while brittle rocks absorb less energy prior to being fractured. Young's modulus or Poisson's ratio calculated from such stress-strain or deformational measurements are referred to as static moduli.

▶ The second type of measurements carried out for the laboratory determination of elastic constants are where velocity is used for their calculation. For example, ultrasonic waves are made to travel through a known length of a rock sample, and the corresponding travel time is determined from the first arrival of both compressional and shear waves.

The Young's modulus and Poisson's ratio computed from these velocities and density are referred to as **dynamic moduli**.

Such dynamic computations could be carried out from sonic log data, as well as seismic surveys – and the only difference between the velocities would be their measurements at different frequencies, namely kilohertz for sonic logs and close to hundred hertz or so for seismic data.

Staticand Dynamic Moduli

The static and dynamic moduli of rocks usually differ from one another – and usually the dynamic Young's modulus is greater that the static Young's modulus.

In a similar vein, the static Poisson's ratio is greater than the dynamic Poisson's ratio.

While the physical causes for the difference between the static and dynamic moduli are not clear, it is believed that the discrepancy is due to the fact that in their analysis, rocks do not behave as elastic, homogeneous and isotropic as they are assumed to be.

Rocks usually behave as viscoelastic, due to many different processes – including the inter-granular cracks arising due to the granular nature of the sedimentary rocks. Such inelastic mechanisms respond differently to the static and the dynamic strain amplitudes and frequency, which is dependent on the properties of the rocks.

One suggestion for this discrepancy is the large difference in the static strain magnitudes, which could reach 10^{-2}, and the strain magnitudes for dynamic wave measurements, where they may be of the order of 10^{-7}. Thus the difference between the strain magnitudes could be between four to six orders of magnitude.

To illustrate this difference, we pick up the measured values of static and dynamic Young's modulus and Poisson's ratio carried out on Baxter shale (from the 2008 SPE paper 115736, by Higgins et al.).

The Upper Cretaceous Baxter shale is located in the Vermillion Basin of northwestern Colorado and adjoining Wyoming. Dry gas production has been established from more than two dozen wells in the Baxter, with over-pressuring seen in them. The silt-rich Baxter has vitrinite values approaching 2 percent, porosities in the range of 2-6 percent, TOC in the range of 1-3 percent and matrix permeabilities of 100 to 1,500 nanodarcies.

Triaxial core samples were conducted on 20 samples drawn from 150 feet of the 2,000 feet of the Baxter shale that represents the over-pressured portion. The samples were subjected to in situ conditions of the confining stress, and the measurements were made in the vertical and horizontal directions such that the stiffness constants in the stiffness tensor could be determined and allow accounting for transverse isotropy in the shale.

It was found that the static and dynamic Young's modulus values measured in the horizontal direction were significantly higher than the Young's modulus values measured in the vertical direction. The measured static and dynamic Poisson's ratio values in the vertical direction are slightly larger than the Poisson's ratio values in the horizontal direction.

A comparison of the plotted static and dynamic Young's Modulus and Poisson's ratio values are shown in figure 3a and b. A well-defined relationship between the static and dynamic Young's Modulus is noticed – but not with Poisson's ratio.

Such variations, when accounted for, can appropriately characterize the inherent stress-strain relationship in the shale. In geomechanical studies, while studying the influence of in situ stress applications on breakouts, enhanced pore pressure or on the wellbore stability, static moduli are used in the calculations.

It therefore becomes mandatory to calibrate the dynamic moduli (which are derived from seismic data) to the static moduli (derived from laboratory measurements), before they are used for geomechanical applications.

Methods for Brittleness Determination

Highly brittle shale formations are more prone to stimulated fractures – and they prove to be more productive in terms of release of hydrocarbons.

These fractures also propagate in the direction of the minimum stress.

In the shallow zone, as the minimum stress is the overburden stress, the stimulated fractures will be horizontal. In the deeper zones the minimum stress direction is horizontal, and thus the stimulated fractures are vertical.

Quartz and calcite are brittle minerals, while clay is ductile. Thus higher content of the former two makes the shale more brittle, and more clay content makes it ductile.

XRD analysis of shale samples may not be carried out commonly, but if available is useful. Their estimation from well data is also done by interpretation of the log curves.

As the presence of TOC enhances the resistivity and reduces the velocity, a combination of these two log curves is usually used for its estimation. It is also determined by geochemical analysis of rock samples.

As stated, its estimation from seismic data is desirable.

▶ Given the mineral content (volume of mineral) of the shale sample, a simple way to estimate brittleness would be to determine the fraction (quartz + calcite)/(quartz + calcite + clay). This fraction is termed as brittleness index.

If dolomite also happens to be present, then it should also be added to both the numerator and denominator of the above fraction.

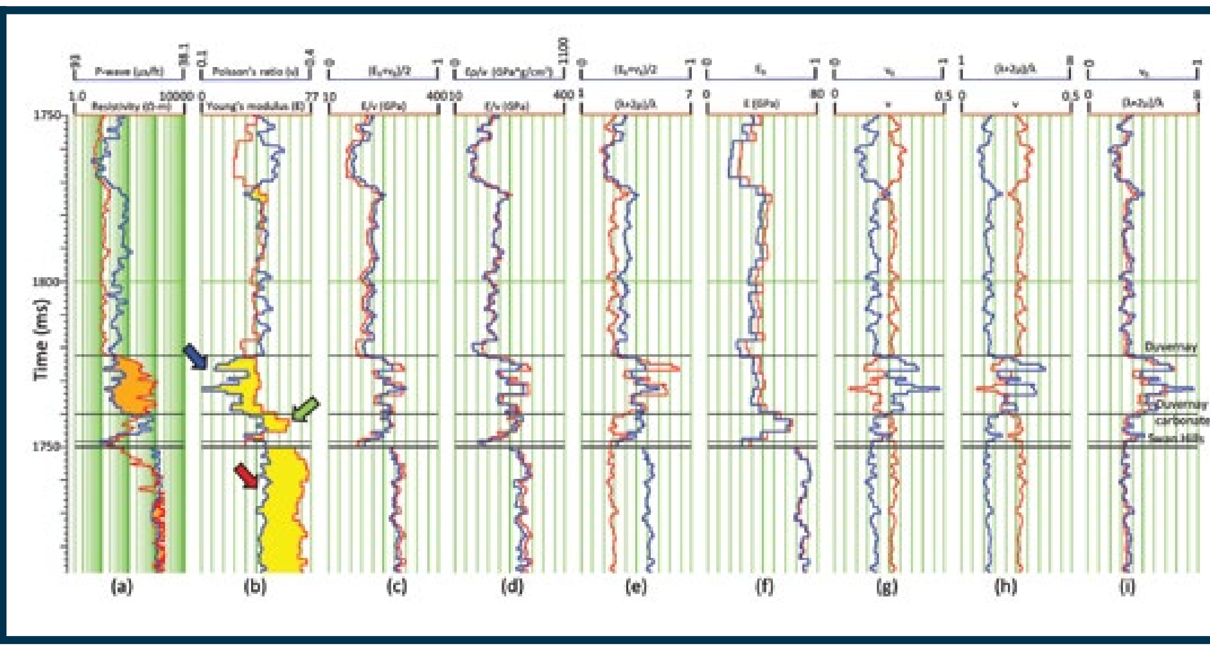


Figure 5 – Log curves from a well in mid-central Alberta showing the Duvernay interval, overlaying Duvernay carbonate and Swan Hills formations. The highlighted orange zone is the crossover between the sonic and the resistivity and could be associated with high carbon content (track a). The crossover between the Poisson's ration and Young's modulus curves is the highlighted yellow zone in track b. Besides the Duvernay, the Duvernay carbonate, which has a high content of calcite and the Swan Hills zones also are highlighted yellow, which is expected. Other brittleness index attributes have been plotted and the text may be referred to their interpretation.

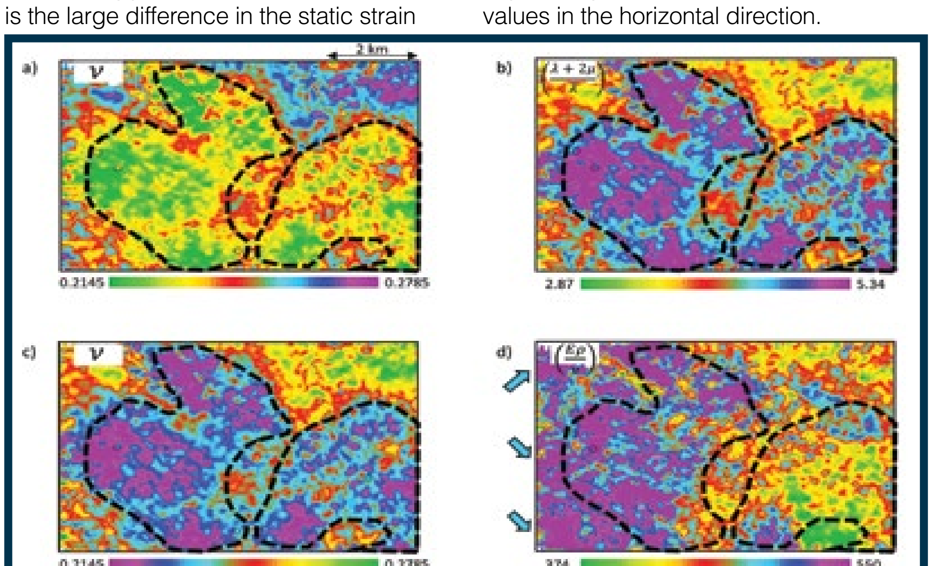


Figure 6 – Horizon slices from (a) Poisson's ratio, (b) brittleness index, (c) the same display as in (a) but with the color bar reversed, and (d) brittleness index. The displays depict the average in a 10ms interval within the Duvernay zone. Apparently, the displays in (b) and (c) look very similar.

See **Discrepancy**, page 42

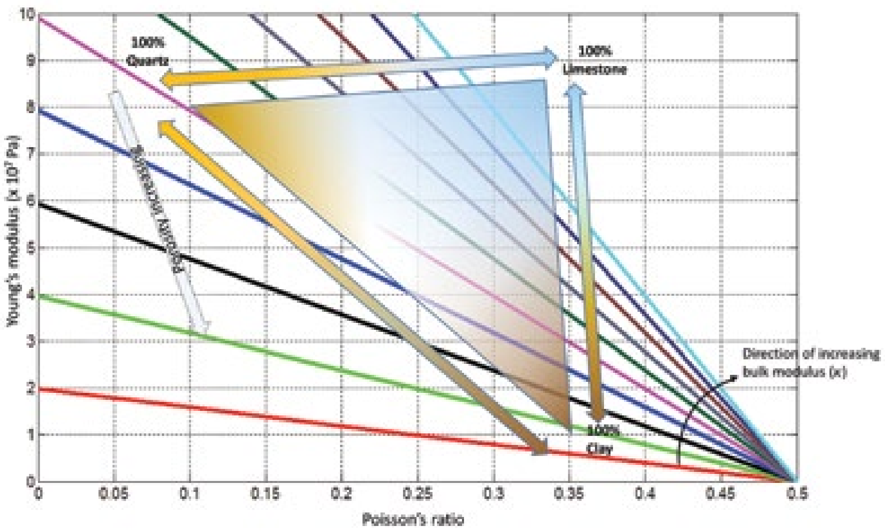


Figure 7 – Rock physics template showing trends in Young's modulus and Poisson's ratio space. Lines of constant bulk modulus are shown increasing from red towards cyan.

Discrepancy

from page 41

Another way to determine brittleness index for a shale sample is to make use of the elastic constants.

One such proposed method makes use of the Young's modulus (E) and Poisson's ratio (ν). For brittle rocks, high values of Young's modulus and low Poisson's ratio are desirable.

Using these constants, the brittleness index can be expressed in a couple of ways:

✓ One is to simply compute the fraction E/ν, which should have high values for brittle rocks.

✓ A variation of this method could be the ratio Eρ/ν. This ratio is especially useful when seismic data is being used for determination of E, which would require the density data. It is usually difficult to determine density from seismic data. Instead, Eρ can be determined which only requires P- and S-impedance, easily derived by impedance inversion of seismic data.

✓ Yet another way is to compute the average of the brittle Young's modulus component and the brittle Poisson's ratio component. That is $(E_B + \nu_B)/2$, where $E_B = 100(E - E_{min})/(E_{max} - E_{min})$ and $\nu_B = 100(\nu - \nu_{max})/(\nu_{min} - \nu_{max})$

Based on the observation that fracturable zones exhibit low values of λρ and moderate values of μρ, another estimation for brittleness index has been suggested and is given as (λ+2μ)/λ.

We discuss the comparative performance of these different methods first on well log data from the Duvernay formation in Alberta, Canada.

The Upper Devonian Duvernay formation is situated within the West Shale Basin in west-central Alberta. The main Duvernay interval is the shale section that shows high values on gamma ray log curves.

A thin zone below the Duvernay interval has a high composition of organic-rich lime-mudstone, and is called the Duvernay carbonate zone – it overlies the Middle-to-Upper Devonian Swan Hills Formation, consisting of a broad carbonate platform overlain with large reefs.

The main Duvernay interval spans the "dry" gas, "wet" gas and the "oil" windows, but at present more interest is focused on the "wet" gas window, where liquid-rich gas is being produced from horizontal wells with multi-stage fracture completions.

In figure 4 a crossplot is shown between E and ν for a zone that encompasses all three zones mentioned above. Separate clusters of points are seen on the crossplot and when enclosed with polygons and projected back on the log curves, these points highlight the individual zones as marked.

The cluster of points from the Duvernay zone exhibit low ν and moderate to high values of E, and thus should be exhibiting higher brittleness.

In figure 5, log curves from a well are shown in different tracks (a) to (i).

In track (a), the sonic and resistivity curves are shown overlaid, and a crossover shaded in orange color in the Duvernay interval is seen. This probably could be the zone associated with high TOC as per Passey's approach.

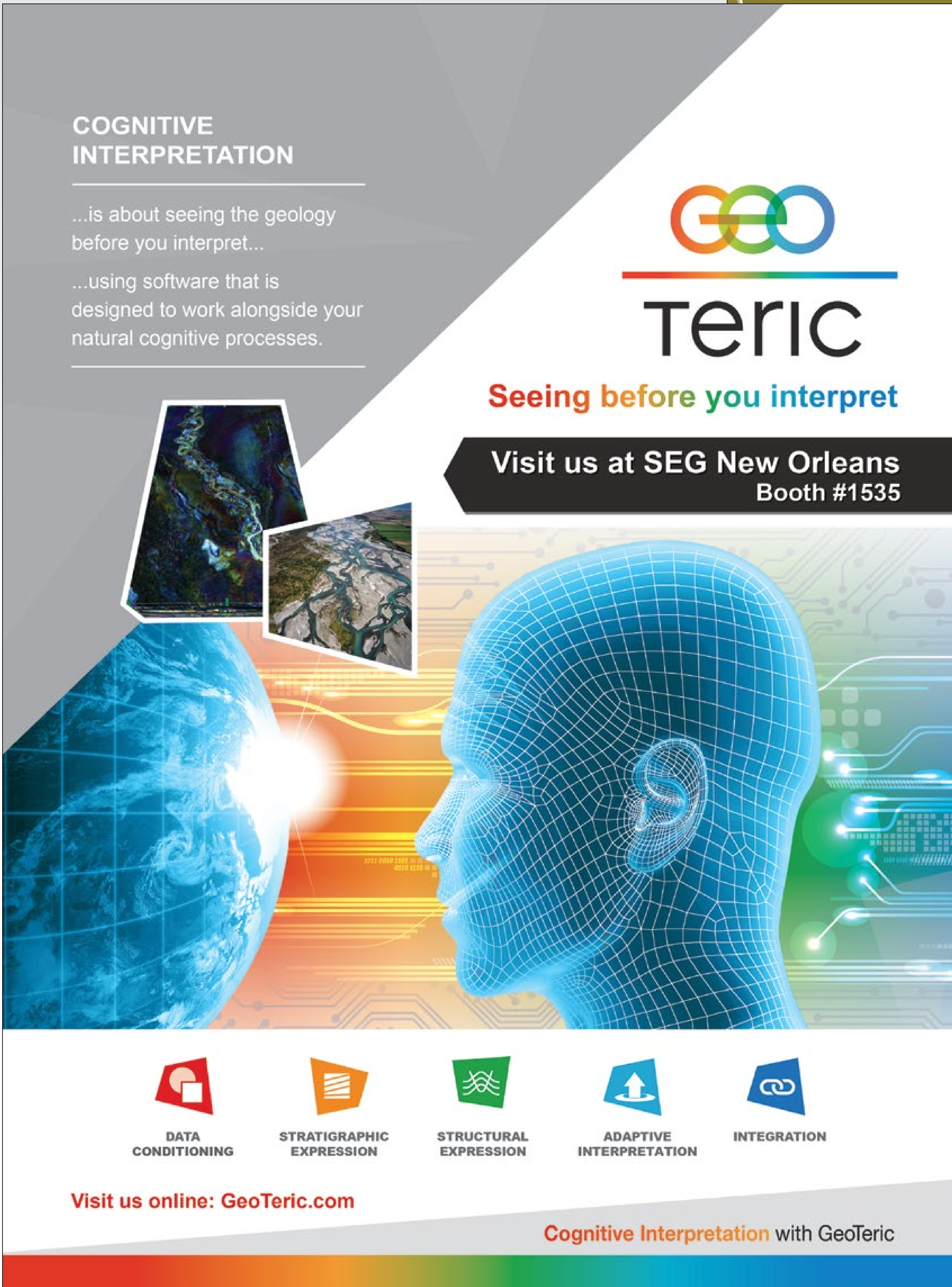
The Poisson's ratio (ν) and Young's modulus (E) curves are shown in tracks (b), and again crossover of curves are seen in the Duvernay interval (blue arrow) as well as Duvernay carbonate zone (green arrow) and Swan Hills interval (red arrow).

We will focus on the Duvernay intervalhere, which is the zone of our interest. Brittleness index curves $\left(\frac{E}{\nu}\right)$ and $\left(\frac{E_B+\nu_B}{2}\right)$ are shown overlaid in track (c). Notice these curves are similar in that they follow each other and small deviations are seen in the Duvernay interval.

Similarly, again brittleness index curves $\left(\frac{E}{\nu}\right)$ and $\left(\frac{E\rho}{\nu}\right)$ are shown in track (d) with very small deviations seen in the Duvernay interval.

Brittleness curves $\left(\frac{\lambda+2\mu}{\lambda}\right)$ and $\left(\frac{E_B+\nu_B}{2}\right)$ are shown in track (e), and these are found to be different. To understand the reason for this difference, we compute the E_B and ν_B components separately and compare them with E and ν curves as shown in

See **Brittleness Index**, page 44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Distinguished Lecturers Announced For 2015-16 Global Tours

The lecturers for the AAPG 2015-2016 Global Distinguished Lecture Program have been announced.

So far, 11 lecturers are touring throughout North America, Asia, Africa, the Middle East and Latin America, with more to be announced soon.

Developed in 1941, the Distinguished Lecture Program continues to be AAPG's oldest and most prestigious program, offering outstanding lectures by speakers who are respected scientific leaders in their disciplines of petroleum geology. Anyone can attend the lectures, which are hosted by AAPG affiliated geological societies or university departments.

Lecturers are sent to AAPG affiliated geological societies and geoscience departments of universities and colleges throughout the world. They are selected for their knowledge in various geoscience topics and are schedule to tour anywhere from one week to three weeks at a time, depending upon their availability.

Information on this year's lineup of Distinguished Lecturers will be included in the November EXPLORER and on the AAPG website under the "Career" menu. E

Brittleness Index

from page 42

tracks (f) and (g). We notice that while the E_B curve appears to be a normalized version of the E curve, the ν and ν_B curves are a reflection of each other.

This latter observation also is seen when we overlay the ν and $\left(\frac{\lambda+2\mu}{\lambda}\right)$ brittleness index curves (track h).

Finally the overlay of ν_B and $\left(\frac{\lambda+2\mu}{\lambda}\right)$ brittleness index curves as shown in track (i) and they look very similar.

When the different brittleness indicators discussed above are computed from the seismic data using simultaneous or joint inversion (for more details on simultaneous inversion see the June 2015 EXPLORER), they also are found to exhibit differences as we notice on the log curves in figure 5.

In figure 6 we show equivalent horizon slice displays within the Duvernay interval (averaged over a 10 ms window) for Poisson's ratio (ν) (figure 6a), $\left(\frac{\lambda+2\mu}{\lambda}\right)$ brittleness index (figure 6b), and $\left(\frac{E\rho}{\nu}\right)$ brittleness index (figure 6d). We notice the Poisson's ratio display shows low values while the $\left(\frac{\lambda+2\mu}{\lambda}\right)$ brittleness index displays shows high values, within the areas marked with dashed polygons.

The equivalent Poisson's ratio displayed in figure 6c in reverse color bar looks very similar to the brittleness index display in figure 6b – an observation made on the two well curves in track (h) of figure 5. Brittleness index curves $\left(\frac{\lambda+2\mu}{\lambda}\right)$ and $\left(\frac{E\rho}{\nu}\right)$ show similar distribution within the dashed polygon on the left, but is different within the dashed polygon to the right, as well as to the left of the display indicated with the blue arrows.

Such difference seen on the different brittleness index curves on these attributes extracted from seismic data are likely to cause confusion while interpreting them.

Delving closely into the determination of the brittleness index attributes in terms of elastic moduli, one finds that the upper and the lower limits chosen for, say E and ν are arbitrary. Thus their interpretation will be done only in a relative sense, and could be seen as a drawback.

Even otherwise, considering brittleness as a mechanical property of rocks, there are no standardized levels above or below which the rocks could be considered brittle or ductile. Instead of just carrying out such a relative or qualitative interpretation of brittleness, more effort could be devoted to understand the rocks physics of the intervals of interest, which could yield an optimal range of E and ν to be considered in our analysis.

For accurate quantification of brittleness, theoretical rock physics templates (including mineralogy, etc.) for the broad intervals of interest can be generated, such that the trends for the lithologies of interest can be studied. With the use of the available well log data, the validity of such templates can be verified for the area of operation.

Finally such templates can be used to interpret the brittleness index displays generated simultaneous inversion (for more details on simultaneous inversion, refer again to the June '15 EXPLORER).

In figure 7, we show such a crossplot template between Poisson's ratio and Young's modulus, where lines pertaining to constant bulk modulus are drawn. Rocks with higher quartz content will generally exhibit lower Poisson's ratio and higher Young's modulus. With increase in porosity, the bulk modulus decreases and so does Young's modulus.

Similarly, more clayey rocks will have higher Poisson's ratio and low Young's modulus. The parameters that we should consider for the possibility of fractures in a shale rock are in situ stress, Poisson's ratio and Young's modulus.

By constructing such crossplots for the parameters in the area of interest, it is convenient to determine the range of values that should be expected for the different elastic constants. This information could then be used during interpretation of those elastic constants derived from seismic data.

Such exercises prove useful for carrying out quantitative interpretation of seismic data. E

(Editor's note: The authors thank their employer, Arcis Reservoir Solutions, TGS, in Calgary, Canada, for encouraging this work and for permission to publish.)

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Edith Allison, director of AAPG's Geoscience and Energy Office in Washington, D.C., can be contacted at eallison@aapg.org; or by telephone at 1-202-643-6533.

New Regulations Loom For Industry

By EDITH ALLISON, Geoscience and Energy Policy Office Director

A burst of new emissions regulations that affect the oil and natural gas industry has cheered the environmental community while distressing the industry and opponents of government regulation.

The Obama administration is rushing to finalize regulations before the Paris climate change meeting and the 2016 election.

Viewed from the industry perspective, the timing of new, costly regulations is an excessive burden on top of low oil prices. Presidential candidates have said little about environmental issues, but many senators and representatives have voiced their support or opposition to environmental regulations – and some conservative candidates propose to eliminate regulations if they are elected.

Therefore, it seems like a good time to look at both the recently proposed regulations as well as the options available for a new president or Congress to counteract them.

However, this is not wholly a politicians' show. Every citizen can submit comments about planned regulations – and these often affect the final rule.


ALLISON

> This is not wholly a politicians' show. Every citizen can submit comments about planned regulations – and these often affect the final rule.

* * *

The U.S. Environmental Protection Agency (EPA) draft rules to reduce methane and volatile organic carbon (VOC) emissions from new and modified oil and gas operations were issued in mid-August and are open for public comment through mid-October at www.Regulations.gov (search EPA-HQ-OAR-2013-0685).

Industry groups have called the rules unnecessary because of industry's success in voluntarily reducing methane emissions while boosting natural gas production. In addition, upcoming standards to reduce ozone will further reduce methane emissions.

On the other hand, environmental groups express concerns that the August rule will not be adequate to meet the Obama administration's commitment to cut methane emissions from the oil and gas sector by 40 to 45 percent from 2005 to 2025.

In addition, the late November-early December Paris meeting of the United Nations Conference on Climate Change may prompt additional emissions regulation by the Obama administration.

The proposed methane- and VOC-emission rules would:

- Require new and modified emission sources in the oil and gas industry to find and repair leaks, use reduced-emission completions on hydraulically fractured oil wells, limit emissions from new and modified pneumatic pumps, and limit emissions from equipment at compressor stations and gas storage facilities.

- Provide recommendations to states on control technologies for use in ozone non-attainment areas and the northeast states Ozone Transport Region.

- Clarify some existing permitting requirements.

- Issue a federal implementation plan incorporating new emissions standards for the oil and gas production industry in Indian Country.

* * *

Given the strong conservative opposition to EPA emissions regulations, an interesting question is what Congress or a new president could do to reverse these rules. What follows is a discussion of options, not the opinions or decisions of any particular candidate.

As the 2016 elections get closer it is worth noting that oil and gas, and coal emissions regulations have specific state impacts, and candidates' positions on the regulations could influence the vote: Ohio, Colorado and Pennsylvania are major oil and gas producers and may be competitive in the 2016 election.

✓ Presidential Options.

A president has two approaches to dealing with regulations with which he or she disagrees: lax enforcement or a new rule-making process.

In the past, lax enforcement has led to lawsuits by a regulation's supporters.

An example of political and legal Ping-Pong with regulations is the EPA 2012 Mercury and Air Toxic Standards (MATS). The Clean Air Act of 1990 and multiple lawsuits prompted the rule. The EPA under President Bill Clinton's EPA decided that MATS regulation was necessary; the EPA under President George W. Bush disagreed. A court challenge tossed out the Bush administration policy and the regulatory process was restarted, although the courts are still considering some parts of the regulation.

See Regulations, page 48

Regulations

from page 46

The second option, a new rule-making process, would be slow and probably complicated.

✓ Congressional Options.

Congress has many options to reduce or delay environmental regulations; few of their options, however, are long lasting – and most will provoke strong opposition.

▸ Congressional hearings are an opportunity to hear from expert witnesses and ask questions that publicize legislators' opinions about a regulation or the regulating agency.

Congress has no formal role in developing regulations, but regulating agencies pay attention to congressional opinions that may be reflected in future agency appropriations or legislation restricting agency activities.

The current Congress may not have sufficient votes to override a presidential veto, which is likely for any attempt to weaken environmental regulations.

▸ Members of Congress can and do lobby the EPA during the development of a rule. Legislators may have access to information important to revising draft rules.

▸ Congress passed the Clean Air Act and other environmental protection laws, which are the basis for many controversial regulations, and Congress can modify the law. In fact, the Clean Air Act was modified several times, although not in ways that would reduce its impact.

Existing congressional and presidential opposition to weakening the Clean Air Act would preclude weakening these laws.

▸ Congress can pass legislation that restricts the implementation of a law. For example, H.R. 1030 (and S. 544), the Secret Science Reform Act of 2015, passed the House in March and has been introduced in the Senate. It would prohibit the EPA from issuing any regulations unless all underlying science is publically available for independent analysis and reproduction.

The bill would effectively prohibit EPA air emissions regulations, which are based on research on human exposure to toxics. Some of this research was conducted many years ago and cannot be replicated because of changes in air quality or lack of public access to protected personal health information.

▸ Congress can withhold funds needed to implement a law; this is a common approach. Under the current fiscal year (FY2015) appropriation law the Fish and Wildlife Service is prohibited from listing the sage grouse as threatened or endangered under the Endangered Species Act. In addition, the House version of the FY 2016 Interior, Environment and Related Agencies appropriation would prohibit the EPA from enforcing a number of regulations, including lowering the ozone standard or requiring states to participate in restricting greenhouse gases emissions.

These restrictions only apply to one year but can be reinstated. For example, the House proposes to extend the prohibition on listing the sage grouse as endangered or threatened.

▸ The Congressional Review Act (1996) allows Congress 60 days to review and overrule new federal regulations by passage of a joint regulation. The congressional resolution would need to be signed by the president or Congress would have to override a presidential veto.

This law was successfully used – only once, in 2001 – to rescind a Department of Labor ergonomics regulation.

The current Congress may not have sufficient votes to override a presidential veto, which is likely for any attempt to weaken environmental regulations.

* * *

In December 2014 the Obama administration announced plans to tighten ozone limits (from 75 parts per billion, ppb, down to 65-70 ppb). The rules will require states to reduce VOC emissions and have the ancillary impact of reducing methane, which is a greenhouse gas that does not contribute to ozone.

At the end of August the proposed regulation went to the White House Office of Management and Budget (OMB) for the final interagency consultations and review of the regulation's impacts. Normally the OMB review takes 60 to 90 days, but EPA is under a court order to release the regulation before Oct. 1.

EPA estimates that the regulation will yield health benefits of $1 billion-$4 billion annually. However, a study conducted for the National Association of Manufacturers estimates that the regulation will cost the U.S. economy $270 billion a year – and raise the cost of natural gas and electricity.

Additional rules to reduce methane emissions in final review by the White House and expected to be released later this year include:

▸ Pipeline safety rules (Department of Transportation).

▸ EPA restrictions on toxic air pollutants from refineries.

▸ Methane venting and flaring restrictions on federal lands (Bureau of Land Management with EPA). E

Satterfield: A Guiding Force in Geoscience Education

By BARRY FRIEDMAN, EXPLORER Correspondent

This year's AAPG Foundation Professor of the Year, AAPG member Joseph Satterfield of Angelo State University, had a unique problem when he first arrived at the school.

There wasn't a geology department – well, not much of one, anyway.

"First and foremost, Joe should be recognized for his efforts in creating the earth science minor program and the geosciences major program."

That's David Bixler, present chair and professor of physics at the school in San Angelo, Texas, and he maintains that without Satterfield, geology at the school is unrecognizable.

Satterfield, Bixler continues, was a guiding force for the school's overall academic environment, including student organizations, guest speakers, fundraising and, lastly and perhaps most importantly, a liaison with the San Angelo's community of science teachers.

For Satterfield, who received his doctorate in geology from Rice University, the recognition is almost embarrassing.

"I am lucky to get an award for doing pretty much what I like to do," he said, maintaining that at the outset the school's needs and his own desires fit nicely.

"I came to ASU in 2003 with experience and interest in working with undergraduates on research projects. I also had enjoyed being the sole geologist in a department," said Satterfield, who also saw an opportunity to expand professionally in this very unique town. San Angelo is a place that is very much a reflection of its university – and vice versa.

One of the dynamics for which Satterfield, who's from Baytown, Texas, is most proud is his ability and willingness to go into the community, talk to high school and junior high school science teachers about the avenues that are available for students willing to apply themselves – avenues that, unfortunately, are often non-existent for poor students in the geosciences at other schools.

Satterfield discovered his love of teaching outdoors while working summers during high school and college at El Rancho Cima Boy Scout Camp in central Texas.

Ask him about influences and he mentions colleagues Andy Wallace, James Ward, Heather Lehto and AAPG member John Oldow, who advised his doctorate research project on Mesozoic structures in the hinterland of the Cordillera.

Oldow, he said, opened his eyes on how to think critically, write well and make a good geologic map.

All skills he brought to Angelo State.

"At ASU," he said, "we have the opportunity to change lives more than at many schools."

There's a good reason for that.

"Hispanic students make up 60 percent of the San Angelo Independent School District enrollment," he said, though the number of Hispanics who graduate with degrees in the geosciences and continue on with is minuscule.

This Satterfield finds ironic.

Continued on next page

AAPG Honorary member and Foundation Chairman James A. Gibbs presents the Professor of the Year award to Joseph Satterfield.

Professor of the Year Nominations Open

Do you know a college or university professor who is setting a gold standard in earth science education?

Nominate him or her today for an opportunity to be acknowledged for his or her efforts.

The AAPG Foundation Professorial Award is granted annually to a college or university professor who has demonstrated outstanding leadership in the field of geoscience education.

The winner will receive:

- $1,000 cash award.
- Recognition at the Annual Convention and Exhibition (ACE) Chairman's Reception in Calgary, Canada next June.
- An engraved, commemorative plaque.

Nominations opened on Oct. 1 and will be accepted until Feb. 15, 2016.

To nominate someone or to get more information about the AAPG Foundation Professorial Award, visit Foundation.AAPG.org/programs/professorial-award.cfm.

Continued from previous page

"Our community and West Texas overall is dominantly rural and many students in our region are used to working outside," he said.

And for as long as he's been at ASU, Satterfield felt it important to reach these students.

"I have the chance to work with high school students (also middle school and elementary) that may not have considered college as an option, and especially geology as an option," he said.

He is constantly refining the best way to sell the idea, to teach the discipline. He has narrowed his approach to six steps:

- Provide many opportunities to learn geology in the field, so that students can experience the process of applying terms and concepts to solving problems with real rocks.
- Emphasize describing what you see at the microscopic scale, hand sample scale, outcrop scale or map levels.
- Sketch, draw, draft and discuss many cross-sections and geologic maps in the field and in the lab.
- Get to know students as individuals.
- Work with a small number of students on undergraduate research projects.
- Provide students with opportunities to learn from professionals in the geosciences – especially AAPG members and those experienced in the Permian basin.

On that last point, he does bring in outside guests and experts. One such occasion was his desire to bring Scott Tinker's award-winning energy film "Switch" to San Angelo.

"The movie was a chance to bring together our students and faculty, San Angelo Geological Society members (an AAPG affiliated society), oil and gas professionals in many areas, and many, many interested community members."

Was it successful?

"The biggest hall on campus filled up!"

Asking a geology professor to name his favorite course is like asking a mother to name her favorite child.

But Satterfield has an answer.

"Field Geology, GEOL 3600, also known as Summer Field Camp," he responded.

The reason? Not surprisingly, it's a five-week course that includes a three-day trip:

✓ San Angelo to the Guadalupe Mountains on the first day.

✓ To far western Nevada the second.

✓ A return to San Angelo from the Big Bend region of West Texas on the last day.

"I also very much enjoy teaching structural geology and igneous and metamorphic petrology," he added.

Satterfield for the past nine years has been working on a project that delves into the easternmost Laramide and younger fold and faults in the Big Bend Region in Texas.

"I am lucky that we have the freedom and support from our department and administration to design and modify new programs," he said. "I am lucky to work in a small program."

Of that and San Angelo he says, proudly yet also modestly, "The big reasons that we are successful is that we focus exclusively on quality undergraduate education. Our program works hard to foster a sense of community between students and faculty, to involve many students in undergraduate research projects and to get students out into the field to work in diverse geologic settings.

"We have an unusual opportunity," he added, "to change lives and improve our region." E

Foundation Contributions for August 2015

General Fund

Patrick A. Ward
Eugene L. Ames III
Thurmon M. Andress
Richard S. Barnett
Mark S. Baum
Teekayu Benjawan
Md Jamil Bin Said
Hege M. Nordgard Bolas
Dudley and Marion Bolyard
In memory of Robert T. Sellars Jr.
Gregory L. Cane
Robert R. Chanpong
Austin J. Cozzens
Daniel Creighton
Brendan C. Curran
Julia M. Davies
John J. Degenhardt Jr.
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Alexander H. MacKay
Alex Mangl
Harry Mei
David A. Miller
David S. Muller
National Fuel Gas Company Foundation
Matching gift/Jianli Yang
James A. Norton
Jeffrey A. Nunn
Patrick J. O'Connell
Michael Oristaglio
J. David Overton
Jack C. Pashin
Alejandro A. Rangel
Rusty Riese and Sarah Springer
Eric D. Robinson
Kweku-Mensah O. Sagoe
Pedro A. Sanchez
Jose A. Sanchez Araiza
John R. SanFilipo
Shell Oil Company Foundation
Matching gift/Hilary Brook
Timothy A. Shin
Jayne L. Sieverding
Michael A. Simms
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Jack M. Thorson
Andrei Tudoran
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Danielle Woodring
Jianli Yang
Robert and Edith Zinn

Amoruso Special Publications Fund

Dan M. Cox

Awards Fund

Julia M. Davies

Teacher of the Year Award
Daniel R. Burggraf Jr.
Ridwan A. Oke

Daniel A. Busch Library Fund

George M. Greene

Digital Products Fund

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Arthur W. Leibold

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Barry S. Smith

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Louisiana State University
Jeffrey A. Nunn

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Texas Tech University
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Distinguished Lecture Fund

Jon P. Herber
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Education Fund

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Grants-in-Aid Fund

Bernold M. "Bruno" Hanson Memorial Environmental Grant
David T. Grace
J. David Overton
Deborah L. Patterson

Edward B. Picou Jr. Named Grant
Jeffrey A. Nunn
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James E. Hooks Memorial Grant
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Robert A. Ortalda

James A. Hartman Student Leadership Summit Fund

Chevron Matching Employee Fund
Matching gift/Richard Ball

Military Veterans Scholarship Program

Thornton E. Anderson
John and Kae Armentrout
In memory of Clem Bruce
George W. Burg
Stephen M. Scott
Paul and Deana Strunk

Visiting Geoscientist Fund

Jon H. Pedersen

The monthly list of AAPG Foundation contributions is based on information provided by the AAPG Foundation office.

PROFESSIONAL newsBRIEFS

Donna Anderson, to affiliate faculty, Colorado School of Mines, Golden, Colo. Previously geological adviser (retired), EOG Resources, Denver.

Steve Appel, to seismic interpreter, Schlumberger, Houston. Previously contract geophysicist, Sequitur Energy, Houston.

Eleazar Benedetto-Padron, to vice president, Ryder Scott Co., Houston. Previously senior petroleum geologist, Ryder Scott, Houston.

Randy Bissell, to geoscience adviser, Headington Energy Partners, Corpus Christi, Texas. Previously senior geoscientist, Headington Oil, Corpus Christi, Texas.

Robert W. "Bob" Broomhall has retired from ExxonMobil Exploration. He will reside in Bend, Ore.

Steve Dorobek, to owner, Dorobek GeoConsulting, Houston. Previously principal geologist, BHP-Billiton, Houston.

Wayne R. Dwyer, has retired as senior staff geologist, Husky Energy, Calgary, Canada. He resides in Calgary, Canada.

David F. Greeley has retired as senior staff geologist, BP America, Houston. He resides in Houston.

John Hoffmann, to G&G operations team leader, Chevron North America Exploration and Production Company, Houston. Previously West Papua exploration team lead, Chevron Indonesia, Jakarta, Indonesia.

Nathan Kuhle, to geologist-global exploration new ventures, Chevron, Houston. Previously geologist-Kitimat upstream, Chevron, Calgary, Canada.

T.A. "Mac" McGilvery, to adjunct professor-department of geosciences, University of Arkansas, Fayetteville, Ark. Previously geoscience adviser-technology and projects, ConocoPhillips, Houston.

David A. Miller, to geologist-reservoir characterization, Devon Energy, Oklahoma City. Previously senior staff geophysicist, EP Energy, Houston.

Michael A. Paulson, to vice president geology, Custer & Wright Oil and Gas Investments, Midland, Texas. Previously geologist, Cholla Petroleum, Midland, Texas.

Brad Ritts, to managing director, Stanford Natural Gas Initiative, Stanford University, Stanford, Calif. Previously team leader, Asia-Pacific new ventures, Chevron, Singapore.

Stefano Santoni, to exploration manager, Dragon Oil, Dubai, UAE. Previously new venture director, TAQA, Abu Dhabi, UAE.

Valary Schulz, to consulting geologist, Dallas. Previously geologic manager, Cinco Resources, Dallas.

Donald A. Soper has retired as manager computer mapping, Arch Coal, St. Louis. He will reside in Meridian, Idaho.

Tom Tomastik, to senior geologist and regulatory specialist, ALL Consulting, Tulsa. Previously geologist 4-retired, Ohio Division Oil & Gas Resources, Columbus, Ohio.

David Weichman, to principal geologist, ConocoPhillips, Houston. Previously senior geomodeler, ConocoPhillips, Brisbane, Australia.

IN MEMORY


LOCKRIDGE

AAPG Honorary member, award winning explorer and former Executive Committee member John Lockridge died Sept. 7 at his home in Pebble Beach, Calif. He was 84.

Lockridge, known as "Mr. Niobrara," started his career with General Petroleum, a subsidiary of Mobil Oil, and eventually started his own company, Mountain Petroleum Ltd. There he established himself as a leading figure in Rocky Mountain oil and gas exploration, applauded and honored as an innovative industry leader whose work led to the rediscovery and development of shallow gas reserves in the Niobrara chalk in eastern Colorado.

For AAPG, he served as vice president in 1982-83; was a Distinguished Lecturer; and received the A.I. Levorsen, Distinguished Service and Norman H. Foster Outstanding Explorer awards.

He was made an AAPG Honorary member in 1987.

* * *

Andrew L. Austin, (Member 1957)
Tomball, Texas, May 2015
Claude B. Anger, 85
Flers, France, Feb. 25, 2015
Roger R. Baekeland, 77
Calgary, Canada, June 8, 2015
David S. Ball, 54
North Richland Hills, Texas, April 15, 2014
George A. Ball Jr., 84
Galesburg, Ill., Aug. 24, 2015
Joseph A. Belvedere, 89
Wichita Falls, Texas, May 7, 2015
Dean M. Bilous, 39
Calgary, Canada, March 13, 2015
Peter Buttner, 83
Niskayuna, N.Y., April 27, 2015
G. Mattney Cole, 73
Lakewood, Colo., Dec. 18, 2014
Michael E. Conefrey, 64
Winchester, Va., Dec. 22, 2014
Clyde B. Cotton, 93
Henderson, Nev., June 9, 2015
Robert A. Doak Jr., 87
Trinidad, Colo., May 16, 2015
Richard A. Edmund, 87
Houston, Jan. 15, 2015
Hubert A. Elliott Jr., 65
Garland, Texas, Nov. 14, 2014
William S. Flores, 87
Lafayette, La., Oct. 22, 2014
James M. Forgotson Jr., 84
Norman, Okla., Feb. 1, 2015
Philip R. Grant Jr., 84
Colorado Springs, Colo., Dec. 4, 2014
Harold T. Henslee, 90
Addison, Texas, April 20, 2015
Edward E. Hickam, 87
Houston, Feb. 19, 2015
Weber R. Holloway, 89
Dallas, Aug. 27, 2014
Kenneth R. Johnson, 90
Houston, Dec. 31, 2014
Charles F. Kluth, 65
Roxborough, Colo., May 25, 2015
William J. Krummel Jr., 86
Lakewood, Colo., July 8, 2015
John Lockridge, 84
Pebble Beach, Calif., Sept. 7, 2015
William S. Marshall, 83
Midland, Texas, May 31, 2013
Thane H. McCulloh, 88
Seattle, June 3, 2015
Raul Mosmann, 73
Rio de Janeiro, Brazil, Oct. 16, 2014
James H. Morris, 93
Lafayette, La., July 6, 2015
Howard M. Orlean, 61
Federal Way, Wash., Aug. 11, 2014
William Rabson, 55
Houston, Dec. 27, 2014
Robert T. Sellars Jr., 81
Highlands Ranch, Colo., July 22, 2015
W. Hoxie Smith, 60
Midland, Texas, Jan. 6, 2015
Lloyd Rex Travis Jr., 92
Katy, Texas, Feb. 15, 2015
Wesley K. Wallace, 64
Fairbanks, Alaska, May 10, 2015
John E. Walters, 89
Durango, Colo., March 23, 2015
Stanley N. Warburton, 85
Lake Charles, La., March 27, 2015
Robert J. Whitson, 52
Houston, May 23, 2015

(Editor's note: "In Memory" listings are based on information received from the AAPG membership department. Age at time of death, when known, is listed. When the member's date of death is unavailable, the person's membership classification and anniversary date are listed.)

You can reach about 37,000 petroleum geologists at the lowest per-reader cost in the world with a classified ad in the EXPLORER. Ads are at the rate of $2.90 per word, minimum charge of $60. And, for an additional $50, your ad can appear on the classified section on the AAPG web site. Your ad can reach more people than ever before. Just write out your ad and send it to us. We will call you with the word count and cost. You can then arrange prepayment. Ads received by the first of the month will appear in the subsequent edition.

POSITIONS WANTED

STRUCTURAL GEOLOGY OR ORGANIC GEOCHEMISTRY, TENURED OR TENURE-TRACK, UNIVERSITY OF ALBERTA

The Department of Earth and Atmospheric Sciences invites applications for a full-time tenured or tenure-track position at the Assistant or Associate Professor level in either structural geology or organic geochemistry.

We are seeking an individual with expertise in the structural geology of sedimentary basins or with expertise in organic geochemistry applied to problems in petroleum systems. An applicant in the area of structural geology will preferably have experience in the interpretation of seismic data. The successful candidate will be actively involved in teaching in the Integrated Petroleum Geosciences (IPG) program, a rigorous one-year course-based M.Sc. program that prepares students to work in the modern petroleum industry.

Current areas of strength within the University include clastic and carbonate sedimentology, geochemistry, hydrology, geomechanics, seismic analysis and petrophysics. The successful candidate will contribute to these strengths by developing an active research program that includes supervision of graduate students, collaborating with other faculty members, obtaining external funding, and teaching undergraduate and graduate courses. The Department is equipped with a variety of outstanding analytical facilities, including stable isotope analysis, radiogenic isotopes and the major and trace element composition, including the new Canadian Centre for Isotopic Microanalysis.

Applicants must hold a PhD in either structural geology or organic geochemistry and have an established research program in an academic or industrial setting in one of these areas.

The search will remain open until filled. For more information, including an address for submission of an application, see the official announcement at the University of Alberta website: http://www.careers.ualberta.ca/Competition/A107924023/. All qualified candidates are encouraged to apply; however, Canadians and permanent residents will be given priority.

The University of Alberta hires on the basis of merit. We are committed to the principle of equity in employment. We welcome diversity and encourage applications from all qualified women and men, including persons with disabilities, members of visible minorities, and Aboriginal persons.

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TWO ASSISTANT PROFESSOR POSITIONS IN GEOPHYSICS CONOCOPHILLIPS SCHOOL OF GEOLOGY AND GEOPHYSICS THE UNIVERSITY OF OKLAHOMA

The University of Oklahoma invites applications for two tenure-track positions in Geophysics at the Assistant Professor rank. One position is in General Geophysics and the second in Applied Geophysics. We seek dynamic colleagues who will teach and supervise geophysics students at all levels, while conducting an aggressive, independent, externally funded research in their field of expertise. The successful candidate should hold a Ph.D., have a demonstrated research record,and an interest in teaching undergraduates and mentoring graduate students.

The General Geophysics applicant should have research interest in fundamental geophysics endeavors that include, but not limited to, geodynamics, potential fields, geodesy, numerical modeling, geomechanics or seismology.

The Applied Geophysics applicant should have research interest in collection of geophysical data and the interpretation of the subsurface for energy, groundwater, mineral, and geothermal exploration. Interest in reservoir characterization and industry experience are also welcome.

The ConocoPhillips School of Geology and Geophysics has a large, vibrant faculty with a broad range of research activities and strong ties to the petroleum industry. The student body includes about 200 undergraduates and more than 100 MS and PhD students. The Mewbourne College of Earth & Energy possesses extensive software and computing labs with PC and Linux platforms networked to our own dedicated cluster within the OU supercomputer center (OSCER). The College hosts numerous industrial consortia, a research institute focused on seismic monitoring, and a field campus in Colorado for field courses in geology and geophysics. The geophysics group conducts multiple, externally funded, research, and maintains a comprehensive pool of geophysical equipment including GPR, seismic (active and passive), magnetic, and gravity instruments, as well as extensive rock physics characterization laboratories. Through collaboration with industry, we have a suite of 3D seismic and microseismic data volumes that are used for teaching, algorithm calibration, seismic geomorphological analysis, crustal imaging, and a range of open source software for lithospheric-scale research. Information about the School and College can be found at mcee.ou.edu.

Review of applications will begin September 30, 2015, and on-campus interviews will start later 2015. The search will continue until the position is filled. The preferred starting date is January 15, 2016, with optional starting date of August 15, 2016. Applicants can apply online at jobs.ou.edu and search listings for the requisition number: 23147 for General Geophysics or 23148 for Applied Geophysics. Applicants should submit a complete vita/resume, statement of research and teaching interests, and a list of five references who can be contacted, including phone numbers, e-mail addresses, and mailing addresses. Questions or information requests may be addressed to Geophysics Search, at (405) 325-3253, or ougeophysicssearchchair@ou.edu.

The University of Oklahoma (OU) is a Carnegie-R1 comprehensive public research university known for excellence in teaching, research, and community engagement, serving the educational, cultural, economic and health-care needs of the state, region, and nation. OU enrolls over 30,000 students and has more than 2,700 full-time faculty members in 21 colleges. In 2014, OU became the first public institution ever to rank #1 nationally in the recruitment of National Merit Scholars, with 311 scholars. The 277-acre Research Campus of OU in Norman was named the No. 1 research campus in the nation by the Association of Research Parks in 2013. Norman is a culturally rich and vibrant town with outstanding schools, amenities, and a low cost of living, and it is a perennial contender on "best place to live" rankings. For more information, visit http://www.ou.edu/content/dam/provost/documents/facultyflipbook.pdf and www.ou.edu/publicaffairs/oufacts.html.

The University of Oklahoma is an Affirmative Action, Equal Opportunity Employer. Women and minorities are encouraged to apply. Protected veterans and individuals with disabilities are encouraged to apply.

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Assistant Professor, Geophysics California State University, Long Beach

The Department of Geological Sciences invites applications for a tenure track faculty position in Geophysics at the rank of Assistant Professor to begin in August 2016. Teaching duties include Geophysics and related subjects at undergraduate and graduate (M.S. degree) levels. The area of research should be in applied, shallow-earth geophysics using seismic reflection and other remote sensing techniques. Qualifications include demonstrated commitment to working successfully with a diverse student population and demonstrated potential for developing and sustaining an independent, externally funded research program involving students. The full position description and application requirements are available at web.csulb.edu/divisions/aa/personnel/jobs/posting/2316/index.html. Review of applications to begin December 4, 2015.

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ASSISTANT PROFESSOR OF EARTH AND ATMOSPHERIC SCIENCES (Hydrogeology/ Groundwater Modeling)

Applications are invited for a tenure track position as Assistant Professor in the Department of Earth and Atmospheric Sciences at the University of Nebraska-Lincoln. The successful candidate will be expected to participate in teaching and curricular development of undergraduate and graduate courses, to advise and direct graduate students, and to develop a rigorous research program that is supported by external funding. It is expected that the research program will focus on the responses of groundwater systems to climate change. Ability to contribute to multidisciplinary water and climate research efforts within Department of Earth & Atmospheric Sciences and across the university will be considered as an advantage. The candidate should demonstrate strong potential for research and teaching and must hold a Ph.D. in Geology, Hydrogeology, or a related field at the time of appointment.

The Department of Earth and Atmospheric Sciences offers B.S. degrees in Geology and Meteorology-Climatology, as well as M.S. and Ph.D. degrees in Earth and Atmospheric Sciences. Primary research areas within the geological sciences include hydrogeological sciences, sedimentary geology, paleontology and paleobiology, petroleum geosciences, and geobiology. Research in atmospheric sciences is focused on meteorological hazards, climate change, and remote sensing. Additional information about our department can be found on our web site: http://eas.unl.edu.

To apply, go to http://employment.unl.edu, requisition # F_150187 and complete the "faculty/administrative form". Applicants must attach a cover letter, curriculum vitae, statements of research and teaching interests, and contact information for at least three references via the above website. We will begin to review applications on October 31, 2015, but the position will remain open until it is filled.

The University of Nebraska is committed to a pluralistic campus community through affirmative action, equal opportunity, work-life balance, and dual careers. See http://www.unl.edu/equity/notice-nondiscrimination.

For further information, contact Dr. Richard Kettler, Search Committee Chair by email, phone, or mail at: rkettler1@unl.edu, 1-402-472-0882; Department of Earth & Atmospheric Sciences, University of Nebraska-Lincoln, 214 Bessey Hall, Lincoln NE 68588-0340.

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ASSISTANT or ASSOCIATE PROFESSOR IN PETROLEUM GEOCHEMISTRY CONOCOPHILLIPS SCHOOL OF GEOLOGY AND GEOPHYSICS THE UNIVERSITY OF OKLAHOMA

The University of Oklahoma invites applications for a tenure-track position in Petroleum Geochemistry at the assistant or associate professor level. The ConocoPhillips School of Geology and Geophysics has a long and distinguished history in Petroleum Geochemistry. We are seeking a creative, dynamic person to help us move forward into new and exciting areas of petroleum geochemical research, in particular, with respect to biomarker and stable isotope studies, and an effective teacher who will educate students so they can move into successful careers. The successful applicant will hold a Ph.D., have an academic background in the geosciences, develop an externally funded research program, and teach undergraduate courses in geology in addition to graduate-level courses in petroleum geochemistry.

The ConocoPhillips School of Geology and Geophysics is housed in the Sarkeys Energy Center. The Petroleum Geochemistry research facilities include wet chemistry laboratories for sample preparation and experimentation, all of which are equipped with fume hoods, chemical and solvent storage facilities, microbalances, ovens, water purification facilities, etc. Instrumentation is state of the art, including 7 gas chromatographs, gas chromatography/mass spectrometry instruments (a Thermo TSQ 8000 GC/MS/MS and two 5975 MSD systems), pyrolysis/gas chromatography instrumentation and high performance liquid chromatographic equipment. Our stable isotope laboratories are equipped with conventional facilities for the off-line combustion, isolation, and purification of gases for stable isotope analysis. The laboratory houses 5 stable isotope ratio mass spectrometers, including a Thermo Delta V Plus, a MAT 252, a MAT 253, a Delta Plus XL and a Delta E for bulk and compound specific stable isotope analyses of organic and inorganic materials via dual inlet and in continuous flow modes using elemental analyzers and gas chromatographs interfaced to the instruments. Information about the School and College, the facilities and the entities that it houses can be found at www.mcee.ou.edu.

Review of applications will begin October 1, 2015. The search will continue until the position is filled. The anticipated start date for the position is August 15, 2016. Applicants can apply online at jobs.ou.edu and search listings for the requisition number: 23149. Applicants will be required to submit a vita/resume, statement of research and teaching interests, and a list of five references who can be contacted, including telephone numbers, e-mail addresses, and mailing addresses. Questions or information requests should be addressed to the Chair of the Petroleum Geochemistry Search Committee, at (405) 325-3253 or ougeochemistrysearchchair@ou.edu.

The University of Oklahoma (OU) is a Carnegie-R1 comprehensive public research university known for excellence in teaching, research, and community engagement, serving the educational, cultural, economic and health-care needs of the state, region, and nation from three campuses: Norman, Health Sciences Center in Oklahoma City and the Schusterman Center in Tulsa. OU enrolls over 30,000 students and has more than 2700 full-time faculty members in 21 colleges. In 2014, OU became the first public institution ever to rank #1 nationally in the recruitment of National Merit Scholars, with 311 scholars. The 277-acre Research Campus in Norman was named the No.1 research campus in the nation by the Association of Research Parks in 2013. Norman is a culturally rich and vibrant town located just outside Oklahoma City. With outstanding schools, amenities, and a low cost of living, Norman is a perennial contender on "best place to live" rankings. Visit http://www.ou.edu/content/dam/provost/documents/facultyflipbook.pdf and http://www.ou.edu/publicaffairs/oufacts.html for more information.

The University of Oklahoma is an Affirmative Action, Equal Opportunity Employer. Women and minorities are encouraged to apply. Protected veterans and individuals with disabilities are encouraged to apply.

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TENURE-TRACK APPLIED GEOSCIENCE, BAYLOR UNIVERSITY

Baylor University is a private Christian university and a nationally ranked research institution, consistently listed with highest honors among The Chronicle of Higher Education's "Great Colleges to Work For." Chartered in 1845 by the Republic of Texas through the efforts of Baptist pioneers, Baylor is the oldest continuously operating university in Texas. The university provides a vibrant campus community for over 15,000 students from all 50 states and more than 80 countries by blending interdisciplinary research with an international reputation for educational excellence and a faculty commitment to teaching and scholarship. Baylor is actively recruiting new faculty with a strong commitment to the classroom and an equally strong commitment to discovering new knowledge as we pursue our bold vision, Pro Futuris (www.baylor.edu/profuturis/).

Baylor seeks to fill the following tenure-track Assistant Professor faculty position within the Department of Geology with specialization in Geophysics, Stratigraphy or Structural Geology, beginning in August 2016. Candidates should possess an earned doctorate in geophysics or geology at the time of appointment. Preference will be given to a candidate with a strong background in pure or applied research who works with subsurface data (e.g., seismic, potential field, well log, rock property, fluid production, or combinations of these data types). The successful candidate should have the potential to attract external funds and to build a strong research program that involves both undergraduate and graduate (M.S. and Ph.D.) students. We seek an individual with a strong commitment to excellence in teaching at the graduate and undergraduate levels. Application Process: Send letter of interest, including statement of teaching and research interests, curriculum vitae, official transcripts, and the names and contact information for three references to: Dr. Jay Pulliam, Chair, Search Committee, Department of Geology, Baylor University, One Bear Place #97354, Waco, TX 76798-7354 (Tel: 254-710-2361; e-mail: appliedgeosci2016@baylor.edu). Applications will be reviewed beginning in September 2015 and applications will be accepted until the position is filled.

Baylor University is a private not-for-profit university affiliated with the Baptist General Convention of Texas. As an Affirmative Action/Equal Opportunity employer, Baylor is committed to compliance with all applicable anti-discrimination laws, including those regarding age, race, color, sex, national origin, marital status, pregnancy status, military service, genetic information, and disability. As a religious educational institution, Baylor is lawfully permitted to consider an applicant's religion as a selection criterion. Baylor encourages women, minorities, veterans and individuals with disabilities to apply.

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Geo-DC Benefits All AAPG Members

By DAVID CURTISS

As this issue of the EXPLORER arrives in your mailbox, a group of AAPG members has just finished another Geosciences Congressional Visits Days in Washington, D.C.

During this annual pilgrimage to the U.S. capital, AAPG members gather with members of our sister geoscience societies to talk to policymakers and their staff about the importance of the geosciences to society. We talk about our shared interests as geoscientists – and each group also has a chance to raise issues important to its members.

Congressional Visits Days is one of the activities coordinated and organized by AAPG's Geoscience and Energy Policy office in Washington, D.C., or as we like to call it, GEO-DC.

This December GEO-DC will celebrate its 10th anniversary.

Over the past decade we have been working diligently to help policymakers – in the United States and abroad – better understand the role that geoscience, specifically petroleum geoscience, plays as the foundation of modern society.

As geologists we take for granted that the general public and elected leaders understand the role geoscience plays.

But they don't.

And while there are many trade associations that represent oil and gas industry interests, until AAPG opened its office there was no group dedicated to improved public understanding of the science of finding oil and natural gas.

That's the niche GEO-DC fills.

Occasionally I get a question about why AAPG, as an international scientific

CURTISS

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and professional association, has an office in Washington, D.C. After all, we aren't the power brokering lobbyists of the sort portrayed on "House of Cards."

That's true, of course, but the real underlying question is: How do non-U.S. members benefit from GEO-DC?

My response is that, in fact, many AAPG members live and work in the United States. Many more work for corporations who have operations in the United States. So policies set in Washington, D.C., affect an overwhelming number of AAPG members, either directly or indirectly.

Finally, the big issues facing our profession and our industry are global, so the messages and approaches we are developing and testing in Washington, D.C., to educate policymakers and the public can be used worldwide.

GEO-DC isn't just for U.S. members; it's for all AAPG members.

That's been a hallmark ever since founding director **Don Juckett** opened the office in late 2005. Don's background at Phillips Petroleum and then as a member of the senior executive service at the U.S. Department of Energy were the right blend of both industry and government/policy experience that enabled us to successfully launch this initiative.

I joined as deputy director on a part-time basis a few months later while working at the Energy & Geoscience Institute at the University of Utah. My policy experience came from my 2001-02 appointment as the American Geological Institute's Congressional Science Fellow, where I worked on Capitol Hill for now retired Rep. J.C. Watts Jr. (R-Okla.).

In late 2007, I moved back to Washington and took over as GEO-DC director from Don.

Our current director, **Edith Allison**, whose background includes both stints in industry and then working for the Department of Energy's fossil energy program, as well as a distinguished career of volunteer service to AAPG, took the reins in 2013 and has been working diligently to expand and grow AAPG's policy activities.

Colleen Newman has more recently joined Edie to help AAPG connect and communicate its message. She brings her legislative and executive branch experience and expansive network in Washington's policy circles to the team.

GEO-DC's mission has three principal elements:

- Advise and educate policymakers, government officials and other science and policy organizations to help them make better, more informed policy decisions.
- Communicate to AAPG members timely and relevant information on policy and regulatory activity that will affect them and their careers.
- Provide AAPG members with an opportunity to engage with policymakers, bringing their unique expertise to policy discussions.

* * *

Congressional Visit Days, like the one we've just concluded, is a prime opportunity for you to get involved in policy activities. In recent years we've had several of our Canadian members participate, and everyone is welcome to join us.

As petroleum geoscientists it is up to us to ensure that policymakers and the public have relevant information about our profession as they assess and evaluate policy options.

AAPG has accepted that challenge, and I urge you to join us.

David K. Curtiss

DIVISIONS REPORT: DPA

Spread the Word About DPA-Sponsored Forums

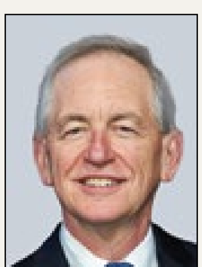
By MICHAEL R. CANICH

As I was traveling at 38,000 feet on my way to the AAPG International Convention and Exhibition in Melbourne, Australia, I read David McCullough's "The Wright Brothers."

Imagine, just 113 years ago, the Wright brothers made the first glider flight, and today I am flying at 500-plus miles per hour. It was their diligence and perseverance that made modern air travel possible.

In the oil and gas industry, the same diligence and perseverance have driven us to develop the current technological advances that have led to discoveries around the world. AAPG's Division of Professional Affairs has developed the Discovery Thinking, Playmaker and Reserves forums, which showcase the thought processes that developed current plays, as well as provide case studies of the results.

Discovery Thinking has been offered as a session at the AAPG Annual Convention and Exhibition since 2008 and at the International Convention and Exhibition since 2011. This forum highlights the AAPG members who have made significant geologic discoveries. The speakers for this forum provide case studies on how they approached a geologic problem and with persistence were able to overcome significant challenges. The testimonies are inspiring and provide every geologist with food for thought regarding their current and



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This complex facet of our industry is becoming increasingly important to corporate survival, and we are planning additional forums in the near future.

future projects.

Charles Sternbach originated and chairs this program for both the DPA and the AAPG 100th Anniversary Committee. In the 14 times this forum has been presented, Paul Weimer, Ed Dolly and other co-chairs also have contributed from around the globe.

For more information about Discovery Thinking, visit www.SearchandDiscovery.com/SpecialCollections/DiscoveryThinking.html.

The Playmaker Forum – a concept also developed and championed by Charles Sternbach – is a compact one-day forum in which geoscientists share with geoscientists, providing technical and professional paths to business success to find and produce energy. The seminar includes educational talks, analog discoveries in proven and emerging plays and a luncheon speaker who had the vision to pursue and successfully develop a new play.

In addition to the educational and motivational talks, Playmakers provides a great venue for networking between the speakers and participants, which include early, middle and late-career petroleum geoscientists.

The initial Playmaker Forum was held in Houston in 2013, with subsequent forums in Houston in 2014; and Midland, Texas; London, England, and Calgary, Canada, in 2015.

Forums for 2016 are scheduled for Denver and Pittsburgh, with additional venues currently developing plans for forums. If you have not attended a Playmakers Forum, please plan to do so in the near future.

For more information, visit www.SearchandDiscovery.com/SpecialCollections/pm.htm.

The Reserves Evaluation Forum is a relatively new addition to the DPA sponsored events, with the first meeting held in Houston on Oct. 31, 2013, in conjunction with the sponsored "SEC Reserve Rules and Unconventional Resources" short course.

This program brought together the giants of the reserves estimations arena, from geological, engineering, geophysical and governmental perspectives. Past President Bob Shoup coordinated the first forum and Eleazar Benedetto-Padron organized the second, again in Houston, on Feb. 26, 2015.

This event requires cooperative contributions from the Joint Committee on Reserves Evaluator Training (JCORET) organizations, and by leading these efforts our members and audience benefit greatly from the knowledge and expertise of the Society of Petroleum Engineers (SPE), Society of Petroleum Evaluation Engineers (SPEE), Society of Exploration Geophysicists (SEG) and AAPG. This complex facet of our industry is becoming increasingly important to corporate survival, and we are planning additional forums in the near future.

The DPA continues to work to provide scientific, business and professional support to its members through the sponsored forums described above. Please join DPA, be part of the effort and help us spread the word about DPA-sponsored forums.


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