AAPG EXPLORER
MARCH 2016

The Great Fields of Egypt

Zohr gas field is the latest in a long line of major hydrocarbon finds.

See page 6

Vol. 37, No. 3
March 2016

PRESIDENT'S COLUMN

The Downturn and Young Professionals

BY JOHN HOGG

It's been a tough 18 months if you are in the energy industry.

For many of us baby boomers and Gen X'ers, we've seen this type of commodity price decline many times in our careers: oversupply leads to a surplus of products, the price drops and companies produce barrels at break-even or a loss and then, unfortunately, organizations cut staffs.


HOGG

Of the five times I can recall this happening in my career, this downturn has a few extra twists that make this time different.

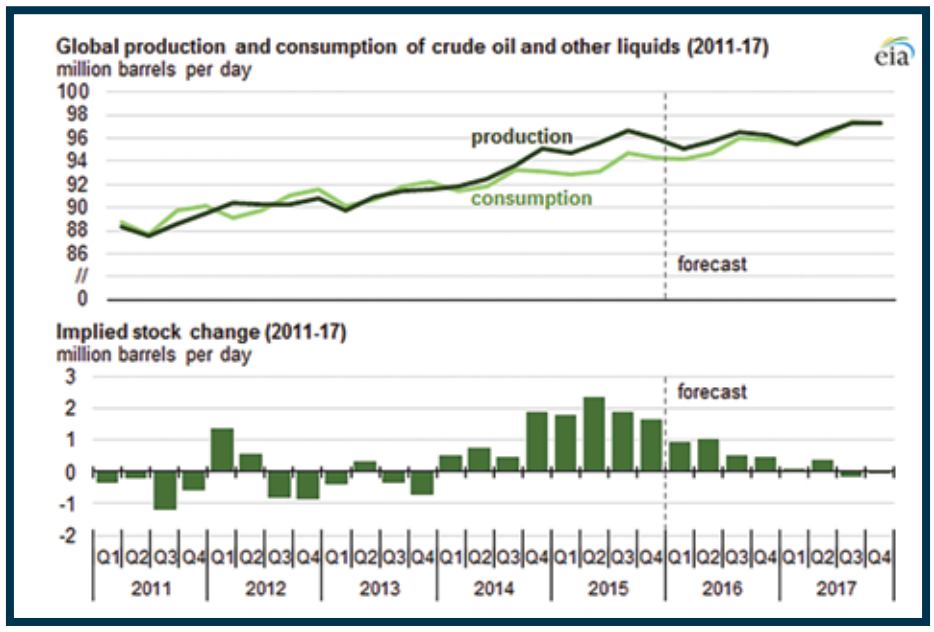
The most obvious is that exploring and producing in North America has changed: unconventional resources cost more to produce due to the reservoirs and the multiple wells needed to maintain a production plateau.

As prices continue to decline, producers will stop drilling and the production decline will be much more dramatic once wells come off their peak production.

Once the decline starts it will take a much greater effort than in the past to build production levels up again. This will require more staff in all the operating companies.

Below is a general look from the U.S. Energy Information Administration (EIA) of the global production and consumption issues. This oil glut started in the first quarter of 2014 and will continue through 2016 before production decreases and consumption overtakes production at about 96 million barrels of use per day.

Second, for most of the professionals who are 55 years of age or older – the baby boomers, people like me – who might have continued to work for three to five more years, are being early-retired, and I believe many will not return to the workforce when the prices recover. Many will opt to leave the industry.



A third consideration is that consumption of oil will continue to grow, even with the "green" energy challenge of the COP 21 United Nations climate forum last December in Paris. As the EIA chart shows, world oil usage moved from 88 million barrels per day in 2011 to 96 million barrels per day by the end of 2017.

People need energy and we will need to provide petroleum and natural gas for decades, so the light at the end of the downturn is that Young Professionals will be in great demand in a renewed and different-looking workforce – a much younger workforce.

The challenge for YPs, then, is how to survive the current downturn and be better prepared for the jobs once they become available in a year or two from now.

As professionals you should all be lifelong learners, thus it should be your job during the downturn to upgrade your technical, business and professional skill sets. Yes, it may take some investment to take courses, but in future job interviews it will also show your commitment to your profession.

Next, I can't emphasize enough that you should all be volunteering. Your volunteer experiences provide you a professional network that will be highly valuable to you in the future. It also provides leadership opportunities for you to:

- Work with others without financial remuneration.
- To learn project management, supervision and time management skills through early volunteer leadership positions.
- Work with diverse groups of geoscientists, many of whom might be older than you, so it can be considered as training for future first-line management.

There are other constructive pursuits while underemployed, like spending some quality time each day learning as much as you can about the related disciplines like land, joint ventures and contracts, as well as building your understanding of health, safety and environment in the workplace; find online drilling, completions and production courses – some at very low or no cost – to upgrade your understanding of the areas of your business.

And when the downturn ends, (it will end) and your résumé will show that you used your time wisely – you built new technical and business skill sets and you exhibited your commitment to your profession.

On a sad note, Toby Carleton, AAPG's president in 1993-94 and Honorary member passed away on Feb. 6, 2016. As a young AAPG volunteer, Toby was the first president that I served with, when I met him on my first assignment on the Advisory Council in 1995.

Toby was a thoughtful, gentle, genuine geologist who had a great passion for AAPG. Through the years, he always had time to stop and chat about AAPG, the industry and his farm out in west Texas. He will be missed by many members. May he rest in peace.

STAFF

Managing Editor
Brian Ervin
email: bervin@aapg.org

Communications Project Specialist
Susie Moore
email: smoore@aapg.org

Art Direction/Production
Matt Randolph
email: mrandolph@aapg.org

Graphics Support
Ben McNett
Kyle Walker

Advertising Coordinator
Steve Praytor
email: spraytor@aapg.org
P.O. Box 979, Tulsa, Okla. 74101
Phone: (918) 560-2647 – fax: (918) 560-2636
(U.S. and Canada only: 1-800-288-7636)
(Note: The above number is for advertising purposes only.)

CORRESPONDENTS

David Brown
Louise S. Durham
Heather Saucier

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Qarun Petroleum Company's oil shipping tanks at Dashour with the Giza pyramids as a backdrop. Photos courtesy of Apache. See story on page 6.

Left – Salam natural gas plant on Apache's Khalda Concession in Egypt's Western Desert.

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Candidate Videos Online

AAPG officer candidates for the 2016-17 AAPG Executive Committee have been announced, and videos that allow the membership to become more familiar with them, their careers and their thoughts are available online, on the Officer Candidates page of AAPG.org.

This year's slate includes contests for four offices. The person elected president-elect will serve in that capacity for one year and will then be AAPG president for 2017-18. The terms for the vice president-Sections and treasurer posts are 2016-18, and the term for elected editor is 2016-19.

The candidates are:

President-Elect

❒ **W.C. "Rusty" Riese**, retired, adjunct professor and lecturer, Houston.

❒ **Charles A. Sternbach**, Star Creek Energy Co., Houston.

Vice President-Sections

❒ **Terence G. "Terry" O'Hare**, Emerald Energy, Dallas.

❒ **Daniel E. Schwartz**, Aera Energy, Bakersfield, Calif.

Treasurer

❒ **Anwar M. Al-Beaiji**, Saudi Aramco, Houston.

❒ **Martin D. Hewitt**, retired, Calgary, Canada.

Editor

❒ **Barry J. Katz**, Chevron, Houston.

❒ **Claudio Bartolini**, Repsol USA, Tomball, Texas.

New App: AAPG Goes Digital

With the advent of smart phones, tablets and other hand-held devices, the world of publications has been revolutionized.

For the past few years, AAPG has received more and more requests to provide access to its journals through a mobile application, and AAPG has answered: We are proud to announce the release of the AAPG Publications app.

As an added value to AAPG members and journal subscribers, the AAPG Publications app is available for both iOS (iTunes) and Android (Google Play) devices and can be downloaded for free.

Both the AAPG Bulletin and the Environmental Geosciences journals can be accessed from the app. AAPG members can simply download and authenticate using their member ID and password. Journal subscribers authenticate using IP address.

Within the AAPG Publications app, readers can access articles, bookmark favorite articles and share them directly from a smart phone or tablet via Facebook, Twitter and email.

Access to the full 100 years of AAPG Bulletin articles is available through the search option, and PDFs of articles can also be downloaded as needed to devices.

The app also contains "Most Read" and "Most Cited" feeds, a link to the AAPG Career Center, and a link to important AAPG deadlines.

The app currently contains the most recent four issues of the AAPG Bulletin. The Environmental Geosciences journal will be launched in the app with its next issue, which is scheduled to release this month (March 2016).

Once the content has built up to 12 months, the oldest issue will be dropped as each new issue is added, so that a rolling 12 months of journal issues will always be accessible directly from the app.

We hope members enjoy this new option for access to AAPG journals.

Any questions, comments and suggestions can be sent to publications@aapg.org.

multi-client seismic
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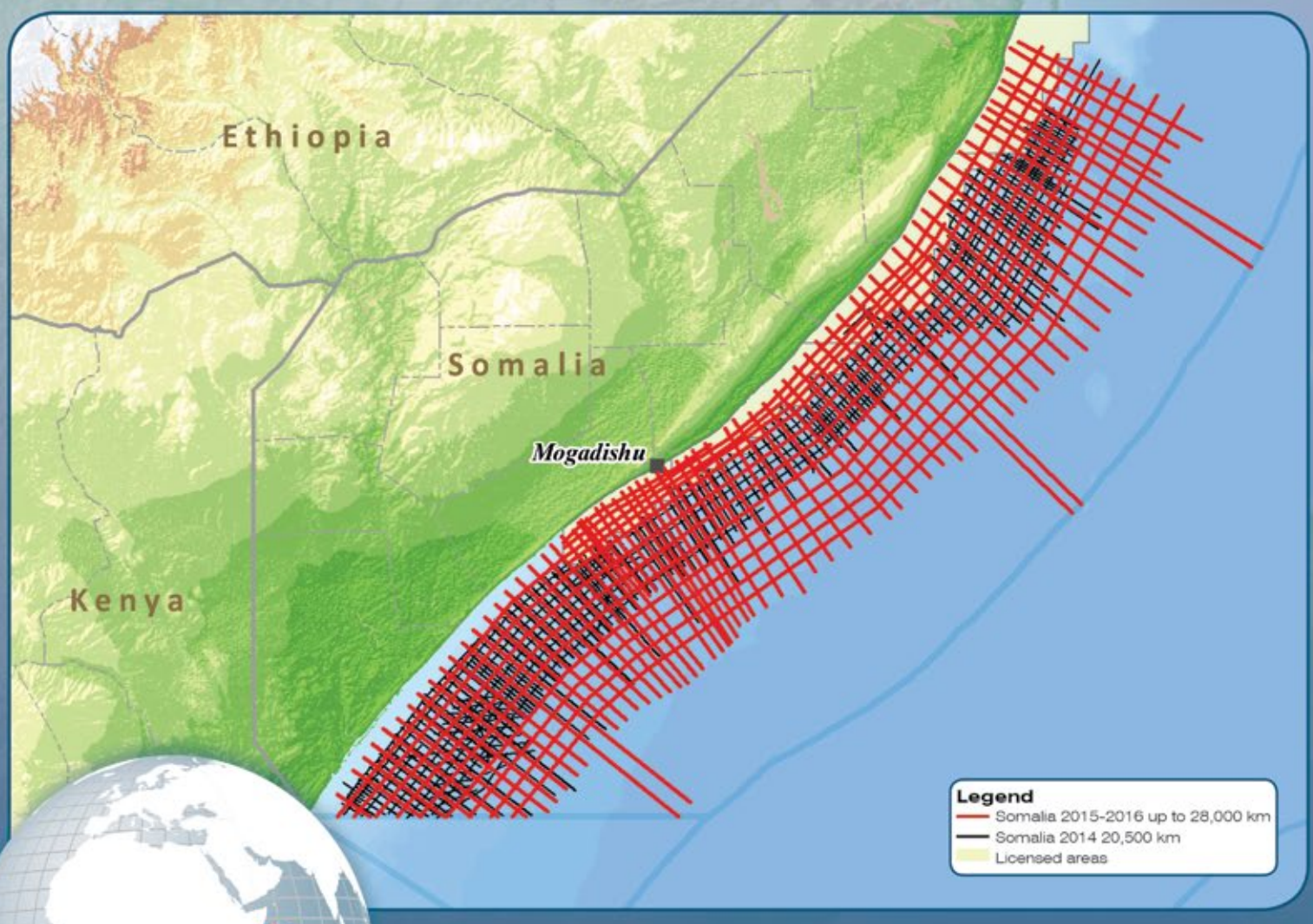
Somalia Unlocked

New 2D Multi-Client Seismic Unlocks Potential



During Q4 2015 Spectrum entered into a co-operation agreement with the federal government of Somalia to acquire approximately 28,000 km of modern 2D seismic. The new acquisition has been specifically designed to complement 20,000 km of existing seismic that was acquired in 2014.

The data is to be acquired at depths of between 30 m – 4000 m, resulting in coverage over the shelf, slope and basin floor with dip, strike and recording time intervals suitable for defining a range of leads and prospects. Streamer lengths of 10,050 m will be used in order to adequately record information at all offsets, further assisting imaging of the underlying syn-rift geometries.

Once completed, modern processing algorithms will be applied to allow optimal imaging of the steeply dipping extensional and compressional features and illumination of subtle amplitude anomalies.

spectrumgeo.com
mc-uk@spectrumgeo.com
+44 1483 730201

Spectrum

Zohr Field: Just the Latest of Egypt's Big Discoveries

By DAVID BROWN, EXPLORER Correspondent

Egypt popped back into the world exploration picture in a big way last year with the discovery of a supergiant gas field offshore, in the Mediterranean Sea.

Eni SpA drilled the discovery well on its Zohr prospect and encountered more than 400 meters of net pay and calculated the new field could hold 30 trillion cubic feet (Tcf) of natural gas. The find hit No. 1 on everybody's list of big discoveries in 2015.

What most people forgot is that Egypt has offered excellent exploration opportunities for decades.

Look at an oil and gas field map of Egypt and you will see:

- Numerous oil fields in and around the Gulf of Suez southeast of Cairo.
- A significant number of gas fields north of Cairo in the Nile Delta area and offshore north and northeast of the Delta.
- A scattering of oil and gas fields generally extending westward from Cairo into Egypt's Western Desert.
- A large cluster of mostly oil fields but also gas fields in the Western Desert area, centered about 100 miles from the Libyan border.

Salam natural gas plant on Apache's Khalda Concession in Egypt's Western Desert.

VERSFELT

> **"In a nutshell, Apache has had so much success because of its operating philosophy."**

Much of the recent Western Desert exploration work has been done by Apache Corp., which has seen tremendous success in Egypt. The company has increased gross production there 12 percent annually since 1996 and generated more than $7 billion of free cash flow over the last six years.

"In a nutshell, Apache has had so much success because of its operating philosophy," said AAPG member Joe Versfelt, regional exploration manager for Apache in Egypt.

That "acquire and exploit" philosophy enabled the company to build up a position of 48,000 square kilometers with 3-D seismic coverage through organic and accretive acquisition and government licensing

"Since 2001, in almost 15 years, we've drilled anywhere from 40 to 100 exploration wells per year and 130 to 240 development wells per year," Versfelt said.

Production takes place under a government-mandated system that can have "some non-intuitive outcomes, depending on the oil and gas price," he noted.

By that, he meant they receive higher production totals in a lower-price environment, as well as lower totals in a higher-price environment, depending on how their share is calculated under the production-sharing contract.

"Apache largely exports its crude oil from Egypt, with some going to domestic supply. It's sold at Brent (pricing) with a modest discount," he said.

AAPG Emeritus member John Dolson helped initiate contemporary exploration interest in Egypt as co-author of a classic paper on the country's petroleum potential in 1999, and has authored and edited several other papers and book sections on Egypt.

Dolson is director of DSP Geosciences and Associates LLC in Coconut Grove, Fla., a senior adviser for Delonex Energy in England and a former officer of AAPG. He gained extensive international experience in a 28-year career with Amoco and BP.

"When I look at Egypt's history, it goes in waves. The Gulf of Suez lasted quite a while. Then the thing that touched off the Western Desert was a joint venture study back in 1999-2000," Dolson noted.

"Apache was the one that said, 'We're buying into it,'" Dolson said. "It's one of the best success stories I've heard in my life."

Egypt's Geology

A great deal has changed in exploration in Egypt since the 1990s, including the level of geological understanding.

"It's hard to believe, but in 2000 you could not find a good map of Egypt with the shapes of the basins on it. That did not exist," Dolson said. "Now there's been a fundamental reinterpretation of the crustal structure out there, and it's ongoing."

Egypt's geology is challenging to understand, and that's no doubt an understatement.

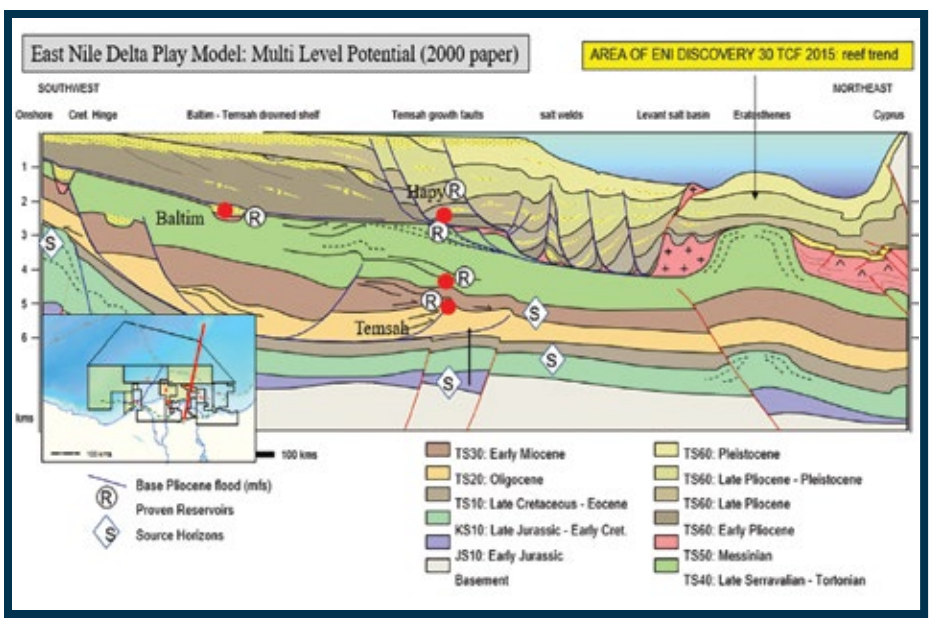
At least a dozen major tectonostratigraphic events have affected traps, seals and petroleum systems. Reservoirs from basement to Pleistocene can be productive.

"We're just surrounded by geology. It's exciting," Versfelt said. "The Jurassic is the main source rock in Egypt. It's a Type 2 to Type 3 source," although source rock possibilities run from Paleozoic through Miocene.

Because fossils are relatively scarce

See **Multi-Path Approach**, page 8

Karama gathering center supports Apache's production operations in the Karama field where Apache's first discovery was in the Abu Gharadig Basin in 2001.



Upcoming Events

midland valley

2016 User Meeting

Houston, 26th April 2016
Glasgow, 10th May 2016

New in Move2016, development plans and demonstrations of advanced restoration workflows

Fault Analysis Training

Houston, 27th April 2016
Glasgow, 11th May 2016

Temporal fault displacement and seal analysis in Move

Fracture Modelling Training

Houston, 28th April 2016
Glasgow, 12th May 2016

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Acquiring 3-D seismic is the key to Apache's success across the Western Desert.

Multi-Path Approach

from page 6

in Egypt's subsurface, Apache uses multiple other methods, especially geochemistry, to help unravel the country's tectonic history and to understand thermal maturities, he said.

That multiple-path approach is "important to understanding the petroleum system and the charge. Egypt is dominated by vertical charge," Versfelt noted.

Dolson and his co-authors raised their estimate of Egypt's undiscovered hydrocarbon resources when they updated the earlier petroleum-potential study. The country held plenty of promise even before last year's offshore strike opened a new exploration area.

"In our 2014 paper we upped the unfound number to about 212 Tcf equivalent, but that was pre-Zohr. Those numbers are going to be proved now," Dolson said.

And Egypt contains a number of different prospective areas for exploration, some of them lightly drilled so far.

"Overall bright lights would still be the Western Desert and the Nile Delta," Versfelt said. "Upper Egypt and the Red Sea, those have different challenges in the low-price-oil environment."

An important note about terminology: "Upper Egypt" is south Egypt. "Lower Egypt" is northern Egypt.

Dolson agreed about the Delta's potential, and also about the current economic picture.

"I think the Nile Delta has a lot of life left," he said. "The Nile is still going pretty good. A lot of that deep stuff is expensive, so we'll see how it works out economically."

"The challenge in Egypt right now is economics, and getting paid. A lot of companies haven't been getting paid. There's a lot of hesitancy," he commented.

The Red Sea

Another extensive area of exploration interest for both Egypt and Sudan is the northern half of the Red Sea.

"The Red Sea has been played time and again for at least three decades. Its secrets really haven't been revealed yet. It will take more seismic acquisition – it needs deep pockets," Versfelt noted.

Dolson said the Red Sea area "has still got some intrigue. The last well Hess drilled there had some oil shows, but no reservoir."

The Gulf of Suez went through an extensive period of exploration and has numerous discovered fields as a result, while more recent drilling interest has shifted to other areas.

"It's fairly mature. But whenever people say things are mature, new things arise," Versfelt noted.

Upper Egypt contains far fewer exploration penetrations than productive areas in the north, but holds intriguing potential.

"Upper Egypt is largely composed of Eocene carbonate cover within basement, but also with some Mesozoic, Jurassic-Cretaceous rifts," Versfelt said.

"Those rifts are unexplored to the south. There's a basin called Komombo and it's in Upper Egypt," Dolson said. "It looks just like the Muglad basin in Sudan. In fact, it's on trend with it. It's a nice little basin – there's tons of structure on it."

And not least, there are the exploration possibilities raised by the Zohr discovery.

Eni said Zohr's structure has a deeper Cretaceous upside that will be targeted with a dedicated follow-up well, but the principal reservoir is in a Miocene carbonate sequence.

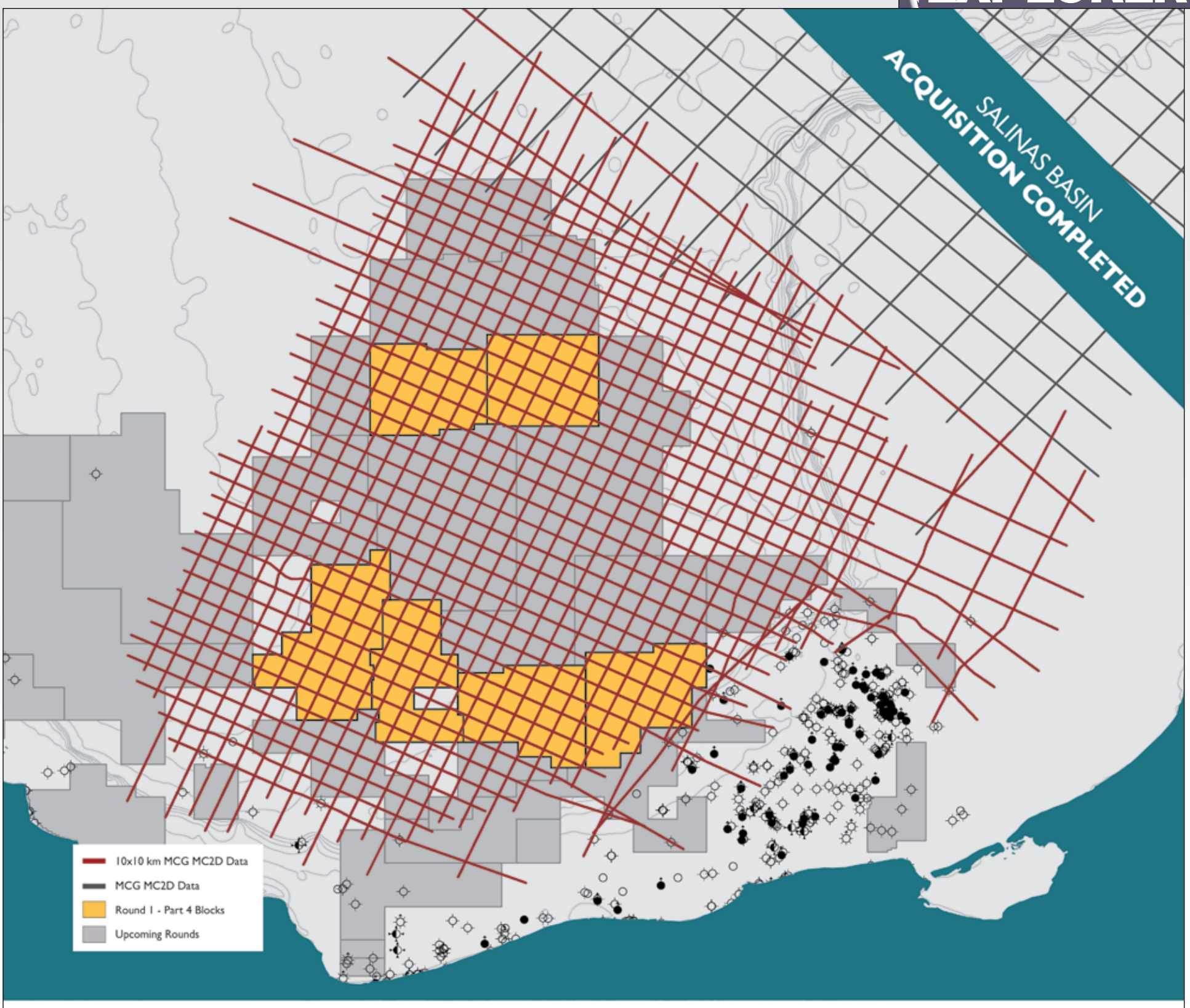
"Zohr is a very recent paradigm shift. While Miocene reservoirs are known here they are clastic reservoirs in Egypt and Israel, and in Cyprus, lately," Versfelt noted.

"Where there's one," Dolson commented, "there's got to be others."

Versfelt said Apache "remains pretty bullish on Egypt overall, with our emphasis on the Western Desert."

He finds the country an attractive place to live in as well as explore.

"Geologically, it is one of the most exciting areas in the world to work," he said. "Egypt is a dynamic place."



‘Faults and Fractures’ Sharpens Seismic Imagery

By HEATHER SAUCIER, EXPLORER Correspondent

As exploration and drilling activities come to a pause during this latest economic downturn, many operators are reprocessing their seismic data with the hope for a new discovery in that data.

Touted as a “revolutionary” fault-imaging attribute, Thinned Fault Likelihood (TFL) is proving to be a relatively new and successful tool for revealing sweet spots and fracture proximity in highly faulted formations, said AAPG member Hesham Refayee, a geoscientist at dGB Earth Sciences.

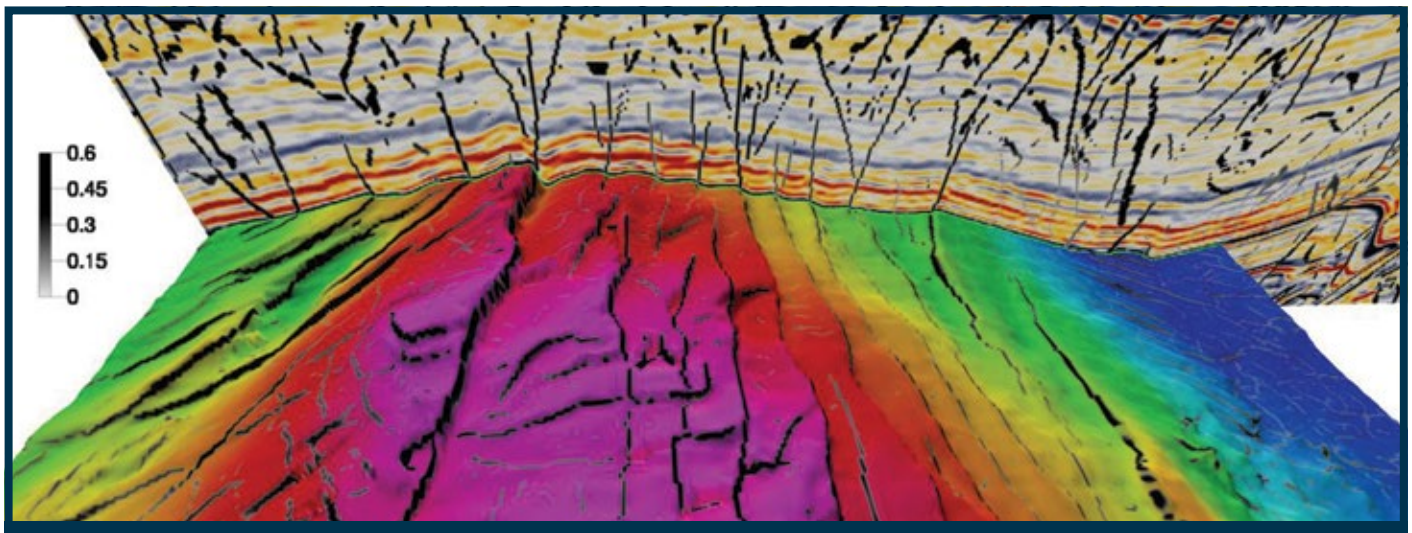
Refayee and other scientists at dGB have developed a commercial plugin around the TFL attribute that allows operators to quickly process seismic data and generate images that are much sharper and more accurate than semblance-based methods, which have been the preferred interpretation methods for visualizing faults.

“TFL is an ideal input attribute to compute fracture density and fracture proximity attributes,” he said. “Fracture density reveals sweet spots in fractured reservoirs, and fracture proximity shows where – in the data – clean, unfractured areas exist.”

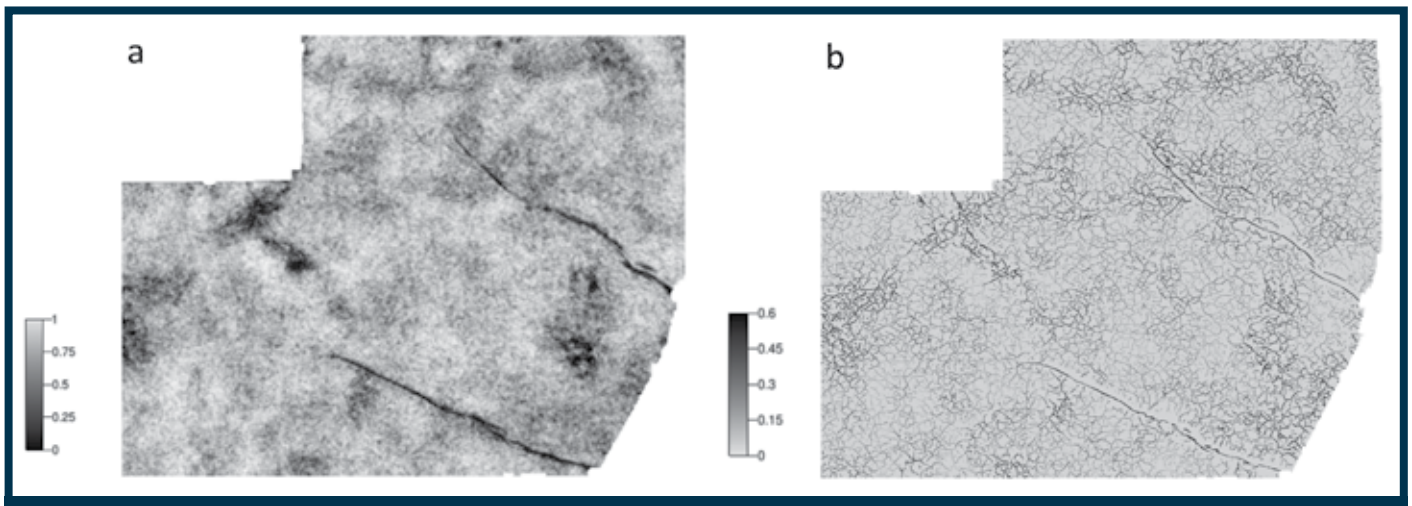
The plugin, called “Faults and Fractures,” combines attributes, filters, fault plane extraction algorithms and various utilities all under one umbrella.

On the market since January, dGB is already selling licenses to the plugin, which is currently being used on seismic data from the Gulf of Mexico and the North Sea.

“This technology really sharpens faults and enhances seismic images,” Refayee said. “This is indeed a step forward in increased profit and reducing risk.”



Shows the new thinned fault likelihood attribute, which is based on algorithms developed at the Colorado School of Mines (CSM). Data from North Sea.



a) Using conventional attribute (similarity or coherency). b) Using the thinned fault likelihood with the new algorithm. The Thinned Fault Likelihood (TFL) helps identifying the dense fractures network and sharpen the faults. Graphics courtesy of TGS.

Man Versus Computer

The idea behind the Faults and Fractures plugin comes from the Colorado School of Mines’ Center for Wave Phenomena. Recognizing a need for better processing for faults apparent in seismic images, geophysics professor Dave Hale and graduate student Xinming Wu developed an algorithm and software that was shared through the university’s open-source Mines Java Toolkit.

Hale recalled their efforts:

Reminding that well data provides accurate measurements of a formation’s density, porosity, permeability and other characteristics, Hale explained that the area between the wellbores is unknown. An important use of seismic data is to help correlate and predict rock properties between wells.

“Geologic faults get in the way of that,” Hale said, explaining that rocks can fracture and slip vertically and horizontally alongside those fractures – faults – between wellbores.

“If you know where the faults are and know how much slippage has occurred, you then know how to correlate rock properties from one side of a fault to the other. We can process 3-D seismic images to find faults, estimate fault slips and undo the faulting, automatically.”

While geologists and geophysicists have been combing though seismic data and picking faults for decades, Hale explained that it can be a tedious and error-prone process, especially for seismic images of formations that are highly faulted.

“Humans are good at seeing things in a photo, a 2-D image. It’s more difficult to see features of interest in a 3-D seismic image, because we can see only a few slices at a time,” Hale said.

REFAYEE

“In contrast, computer programs see better in 3-D than in 2-D. In computing attributes like TFL, we process the entire 3-D seismic image simultaneously, not just the few slices visible to a human seismic interpreter.”

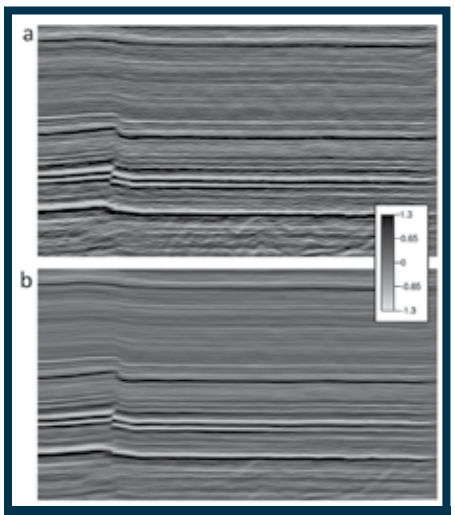
Hale added, “Software for automatically picking faults has been commercially available from others for many years. Our open-source programs are freely available, and include some computational tricks that make our algorithms accurate and fast; but you must be a programmer to use them.

Fortunately, others are making these same algorithms available in software that can be more widely used.”

Making It Commercial

With no doubt that Hale’s algorithm would benefit the industry, especially as the shale boom picked up momentum, Refayee and his colleagues worked for nearly a year to develop a plugin that would be compatible with OpendTect, dGB’s free, open-source Seismic Interpretation Software System.

A higher level of the software is available commercially as well. OpendTect Pro, the commercial version for professionals, was launched in January. It marks the transformation of a seismic interpretation platform mainly used by specialists into an easy-to-use platform for generalists as well as specialists.



a) Original seismic. b) Smoothed Seismic. The new algorithm filters seismic data and produces clear images. Note the sharp edge of the fault.

“OpendTect Pro is a good source for a student researcher and the industry to use,” said AAPG member Nanne Hemstra, dGB’s executive vice president – Americas. “It is made for beginners, specialists and those who want to go into more high-level interpretation workflows.”

In essence, the plugin automatically extracts fault planes, un-faults seismic data and computes feature-specific attributes – namely fracture density and fracture proximity.

Refayee has demonstrated its ability using the Utica Shale formation, which is noted for its large reserve of oil and gas, thickness and fault density. “Utica is one of the most significant unconventional reservoirs in the United States,” Refayee said. “It’s very important in exploiting unconventional reservoirs to understand the tectonic history of the area you are studying.”

Furthermore, the Faults and Fractures plugin facilitates the smoothing of data, reducing the noise of seismic data while simultaneously enhancing features of interest, said Refayee, stressing that the exact position of faults and fractures must be known in order to maximize recovery of stimulation work.

“It’s crucial to know where the faults and fractures are and highlight this discontinuity without removing the characteristics of the seismic,” Hemstra said. “This is often a challenging job because any filtering you do also affects your seismic. This technology preserves the seismic characteristics and highlights the faults and fractures.”

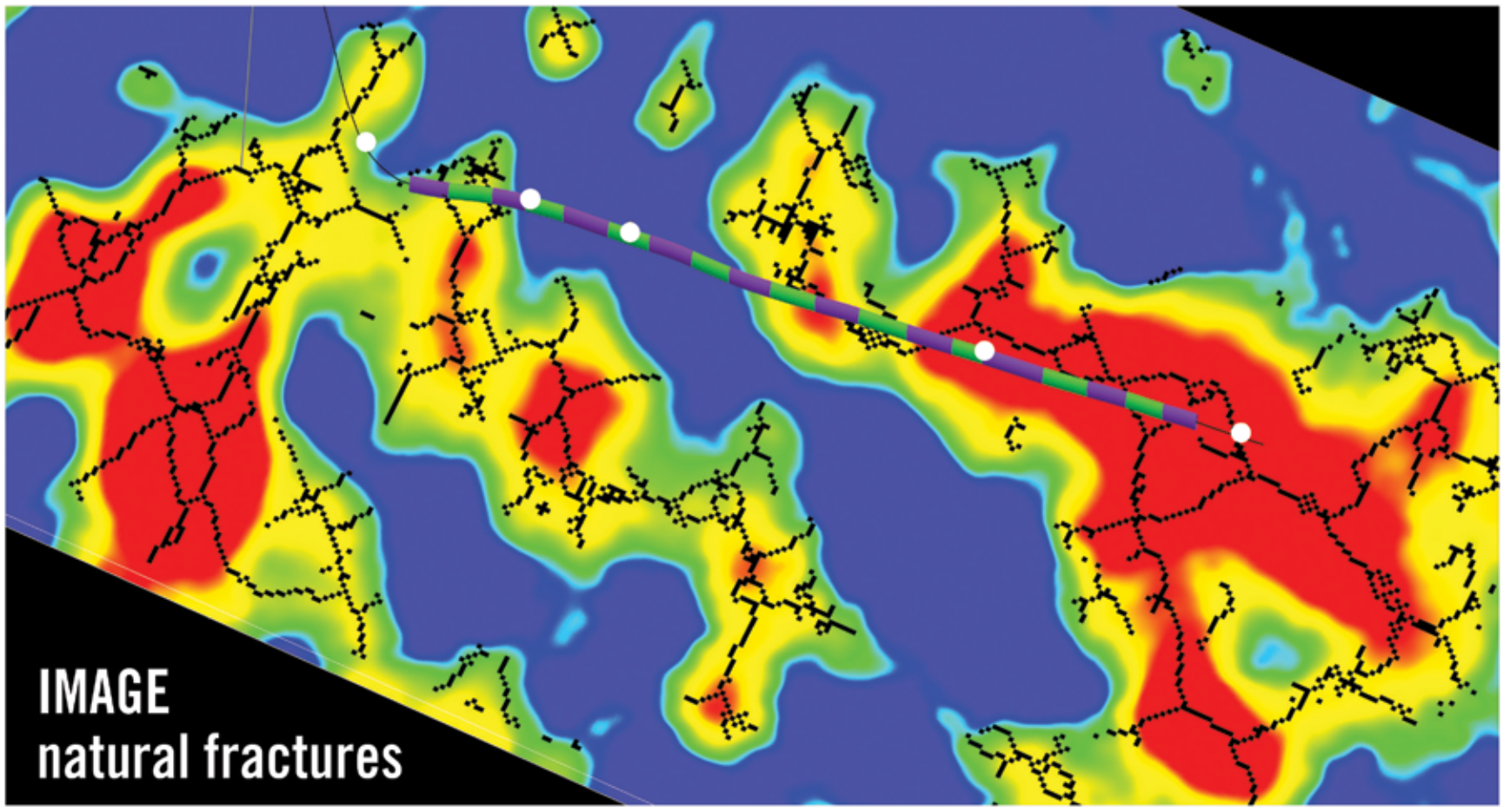
TFL is important as it produces thin lines on 3-D section volumes to highlight faults and fractures, said Hemstra, explaining that thin lines give more detail.

“This helps us to determine which areas are more frac’able than others,” he added.

Convinced of the plugin’s value, several companies have already purchased licenses since its January launch, Refayee noted.

“People think it’s worth investing in. We have had positive feedback from clients,” he said. “We believe that this technology provides excellent return on investment. It is affordable and the outcome is really significant based on the results that we have seen so far.”

Refayee added: “Despite the current downturn, we believe this technology can give oil company operators or a consultant, the ability to enhance their benefits and reduce budget costs.” E



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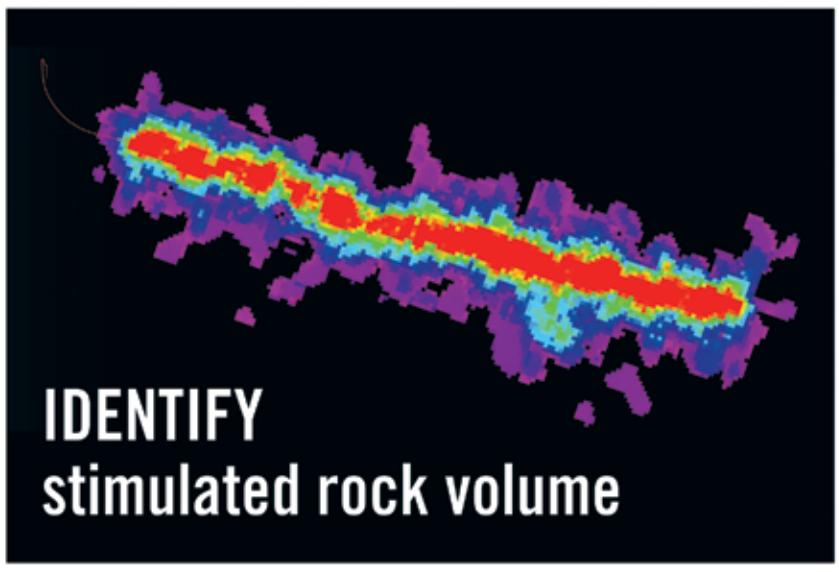

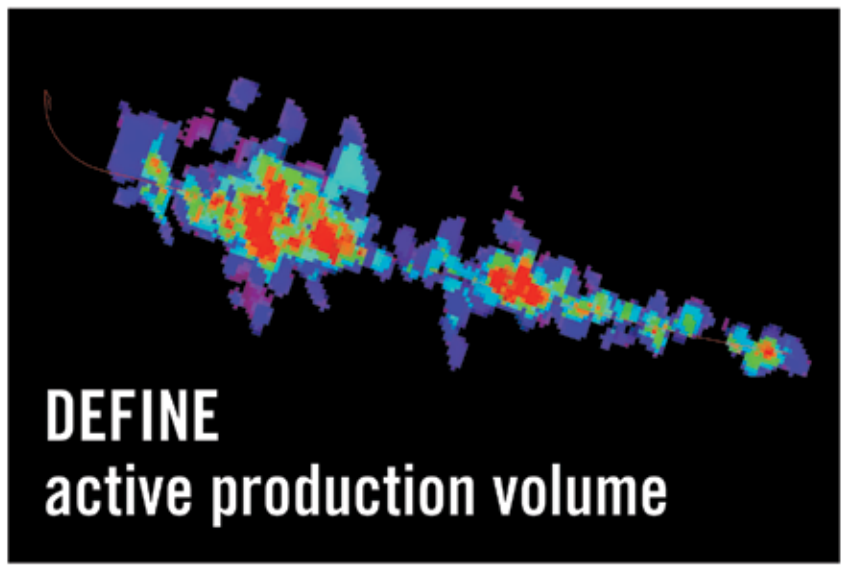

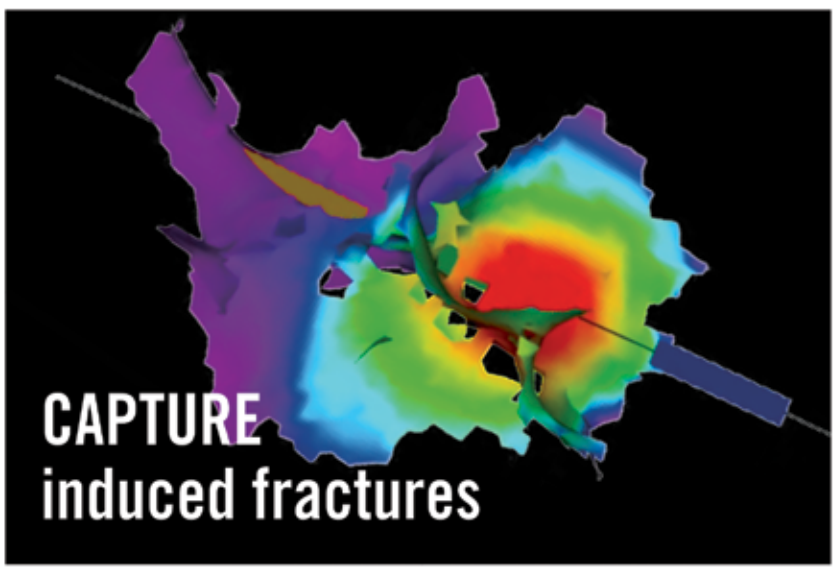

Global Geophysical's innovative approach to ambient seismic provides direct imaging of acoustic activity in the subsurface. This allows us to identify areas or zones that are acoustically active due to natural fractures, hydraulic stimulation or production-related activities. Our ambient seismic results can be presented as 3D attributes, as discrete volumes of acoustic activity or as Tomographic Fracture Images[sm].

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Seismic interpretation

‘Computers Can’t Replace Geologists’

By DAVID BROWN, EXPLORER Correspondent

Computers have taken on more and more of the load in seismic interpretation.

But advances in computational seismology and the use of seismic attributes won’t remove the geologist from the equation.

“Our task is to help the geologists do their interpretation,” said Sergey Fomel. “We cannot always replace geological insight with what we extract from the data.”

Fomel has a joint appointment at the University of Texas at Austin.

As a member of the faculty, he serves as Wallace E. Pratt professor of geophysics in the university’s Jackson School of Geosciences.

FOMEL

> “We cannot always replace geological insight with what we extract from the data.”

He’s also a researcher in the school’s Bureau of Economic Geology (BEG) for the Texas Consortium for Computational Seismology, a joint initiative of BEG and the UT Center for Numerical Analysis at the Institute for Computational Engineering and Science.

In the latter role, he sees the latest trends in computer-assisted seismic interpretation and use of seismic attributes.

Current Trends Aren’t Necessarily New Trends

Not that he thinks all the trends are cutting-edge.

Some of those developments “are, in my opinion, not new developments,” he said.

Progress sometimes involves perfecting approaches that were developed in the past. Still, new advances in computer-assisted interpretation have taken place in just the most recent two years.

Fomel sees these as some of the current trends:

- Automating Seismic Interpretation:

The interpretation process “typically involves a lot of manual activity, which is sometimes important activity because it requires geological insight. But it also can be tedious,” Fomel noted.

- Advances in Picking Horizons and Identifying Features:

“There are some new exciting algorithms where we can pick more than a human interpreter possibly could,” he said.

- Better Implementation of Concepts:

“Some of those involve highlighting discontinuities and measuring curvatures in the seismic horizon,” he said.

A Wide Umbrella

Fomel earned his doctorate in geophysics from Stanford University after working at the Russian Institute of Geophysics and the Lawrence Berkeley National Laboratory.

He received the J. Clarence Karcher Award from the Society of Exploration Geophysicists in 2001 and the Conrad Schlumberger Award from the European Association of Geoscientists and Engineers in 2011.

A quick review of the titles of some recent papers co-authored by Fomel shows the wide-ranging nature of today’s research in computational seismology and seismic attributes:

- “Viscoacoustic modeling and imaging using low-rank approximation.”
- “Seislet-based morphological component analysis using scale-dependent exponential shrinkage.”
- “Random noise attenuation using local signal-and-noise orthogonalization.”
- “A fast algorithm for 3-D azimuthally anisotropic velocity scan.”
- “A robust approach to time-to-depth conversion and interval velocity estimation from time migration in the presence of lateral velocity variations.”
- “Source-receiver two-way wave extrapolation for pre-stack exploding-reflector modeling and migration.”

Computational seismology adds the computer as a tool to assist geoscientists who analyze and interpret seismic data.

“We deal with computation of various types. Traditionally in seismic, more of the resources are spent on imaging,” Fomel said. “The other side of it is doing seismic

See **Research Challenges**, page 16

Airgun Alternative In Development For Seismic

By LOUISE S. DURHAM, EXPLORER Correspondent

Airguns have long been the industry standard sound source used by crews to acquire seismic data in the marine environment offshore.

The driving mechanism for airguns is supplied by compressed air, and the devices create considerable noise when large volumes of air are emitted. These intense pulses of acoustic energy act as a signal, traveling downward through the water and ultimately triggering a series of refractions and reflections off the varied horizons present in the target subsurface area.

This popular and effective sound source technology has remained essentially static through the years.


BURNETT

> "If we cut down on the energy level, then the acoustic footprint is smaller and you get better resolution on your seismic work."

Change, however, is afoot.

The technology has drawn criticism from environmental activists and federal policymakers and regulators for its supposed impact on sound-sensitive marine life like whales and dolphins. The validity of those criticisms has been a continued source of debate, particularly with the passage of the Marine Mammals Protection Act (MMPA) in 1972 and its various amendments in the decades since.

What isn't debatable, however, is the political and social pressure on the seismic industry, and as a consequence, the industry had to begin re-thinking its surveying methodology, specifically regarding noise creation in the marine environment.

Building a Better Acoustic Source

But developing acceptable source alternatives to the airgun is a complex endeavor.

In addition to the necessity to reduce noise levels, companies must address their own needs as well. Ensuring signal quality comparable to or better than the proven airgun method in order to arrive at an equal or, ideally, superior end-product ranks high on the list.

With the MMPA in place, regulators eventually moved to enforce varied requirements on the data gatherers.

These included placing a marine mammal observer onboard working boats to be on the lookout for any and all marine life, along with monitoring systems to pick up on any and all mammal activity within the shoot area.

So, industry participants are busy working to develop, among other options, a marine vibrator that is commercially and technically viable to serve as a preferred sound source for many marine seismic survey operations.

The big differentiator here is that airguns with their loud blasts of noise are impulsive sound sources, as opposed to the controlled-source marine vibrators.

An independent joint industry project (JIP) is focused on development and testing for an acceptable substitute for airguns.

Sponsored by three of the industry majors, ExxonMobil, Shell and Total, the JIP has received considerable attention, along with individual companies engaged in this type research.

After reviewing a range of vendors, the JIP contracted with three of them – PGS, Applied Physical Science, and Teledyne Webb Research – each charged with designing and building a prototype marine vibrator suited for use in offshore data acquisition programs.

In so doing, the vendors must adhere to a set of specifications for the prototype established by the founding sponsors.

The JIP is managed by Texas A&M University's Global Petroleum Research Institute (GPRI).

The output specs and reliability requirements for the marine vibrator are comparable to the kinds of airgun arrays now being used, according to Mike Jenkerson, geophysical adviser for marine seismic at ExxonMobil.

He and a couple of industry colleagues succinctly emphasized the motivation for the project:

- Mitigating some of the environmental objections to seismic surveying in certain parts of the world.
- Delivering additional geophysical and operational benefits, such as shallow water operations, improved bandwidth control and signal encoding capabilities.

See **Smaller Footprint**, page 16

Smaller Footprint
from page 14

Jenkerson noted that many of the techniques now used to improve operational efficiency for land vibrators could be adapted for marine vibrators.

A Smaller Footprint

David Burnett, technical director of GPRI, who serves as technical administrator for the program, elaborated further on the effort.

"The goal is to create an energy source for offshore sites and transition zone waters that has more directed acoustic signal," Burnett said. "If we cut down on the energy level, then the acoustic footprint is smaller and you get better resolution on your seismic work.

"The ultimate goal is to find a place where you have a sensitive environment and you don't want to come in and run the seismic boats (with airguns)," he noted.

"We anticipate that with a marine vibrator having a smaller environmental footprint, it's going to be easier to get access and less expensive overall to run these things.

"The majors want the technology to be developed and to get far enough along so the industry will adopt these measures and utilize," Burnett added. "They're taking some of the risk out of research that the offshore seismic people would have to do."

The program is making steady progress.

"We'll have performance and reliability test data this year," Burnett said. "By 2017, we'll have equipment testing in the open water environment, and the information will be public.

"We want all to get tested and hope they test out well enough that we get three really good (systems)."

Burnett pointed out some of the nuances in the designs, including weight, power and technological complexity.

He envisions that when offshore exploration picks up again, some of the companies will have an option to choose either marine vibrators or airguns for data gathering.

"This offers a future for offshore exploration that meets more expectations," he said. "You're a better neighbor, so it's better to have."

Research Challenges
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data analysis as it relates to interpretation."

Current research challenges cited by the computing consortium include estimating seismic velocities by using full waveform information, identifying most-accurate and most-efficient imaging algorithms while controlling the trade-off between accuracy and efficiency, and assisting the seismic interpreter by automating common interpretation tasks.

Automating manual tasks is an especially meaningful problem, but it can be a tricky one, according to Fomel. He said hand-work in seismic interpretation can be so repetitive it becomes a health hazard.

The Human Factor

At the same time, hands-on interpretation allows geoscientists to bring personal knowledge and experience to the task.

"We need to bridge the gap between manual interpretation, which brings in the geological insight and computational seismology," he said.

Fomel cited the example of 3-D seismic interpretation of salt bodies in the Gulf of Mexico.

Computer programs and inexperienced interpreters faced with a choice can easily pick a false bottom for salt, but geoscientists who have worked in the Gulf will more often make the correct choice.

"They can tell from their experience which is more likely," he said.

Another challenge for computer-assisted interpretation is combining seismic data with information from well logs and other sources. That's a decades-old issue, but new developments in exploration and production make it a timely problem, Fomel observed.

"It is especially true today because the scale that's of interest in unconventional resources and nonconventional reservoirs is smaller than what we can detect in usual seismic," he said.

Seismic interpreters use computers to help identify subtle features, another important area of study. Fomel has conducted research into what he calls "predictive painting," or using a numerical algorithm for automatic spreading of information in 3-D seismic volumes according to the local structure of seismic events.

"In time-frequency analysis we also are developing new methods. This is important, again, in recognizing subtle features," he said.

Seismic attributes are extracted or derived from seismic data and commonly used to enhance understanding, for a better geological or geophysical interpretation. The most commonly used attribute is seismic amplitude.

Advances in identifying, quantifying and utilizing seismic attributes continue, Fomel said, but the industry's uptake of new developments can be slow.

"A lot of interpreters still have some mistrust of attributes, so they don't understand how attributes can help them," he noted.

Seismic imaging no doubt continues to receive the biggest share of investment in seismic computing. But Fomel has noticed an increasing interest in computational seismology, in tools for seismic data analysis.

"We see more companies putting money into computational tools," he said. "I see it as a new trend, but some companies are doing it."


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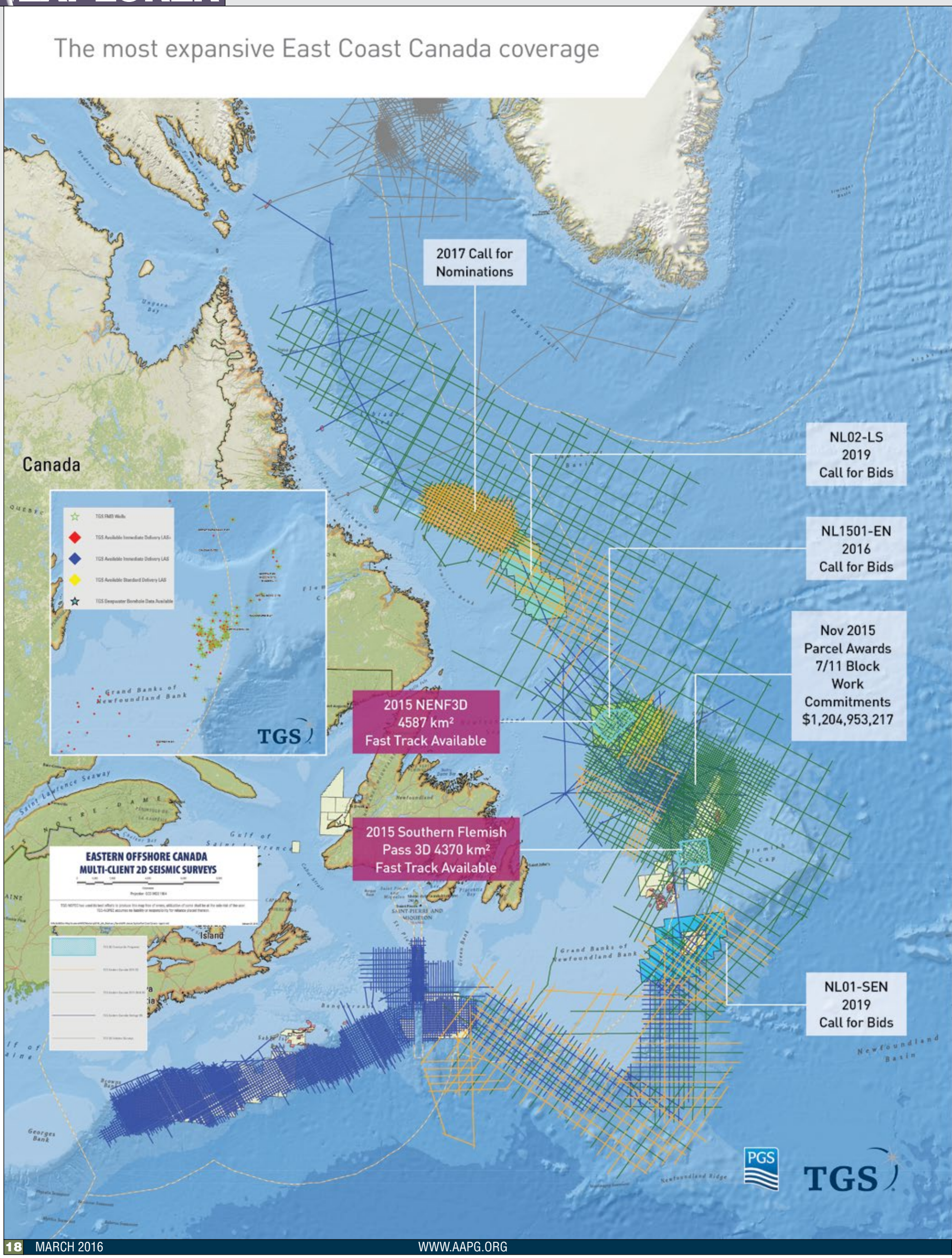

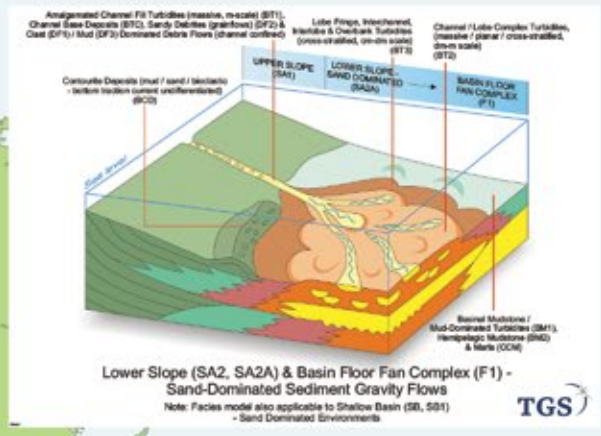

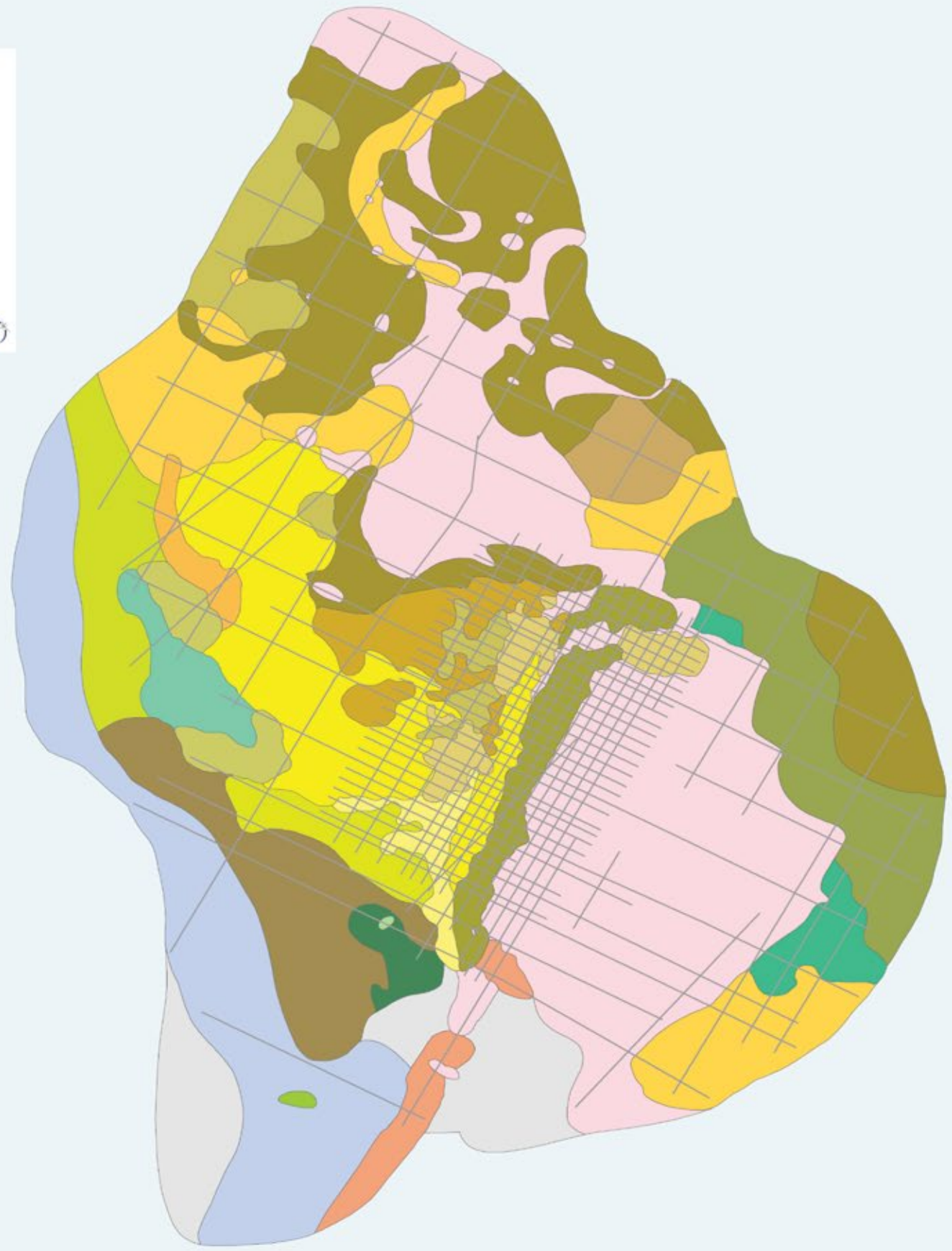

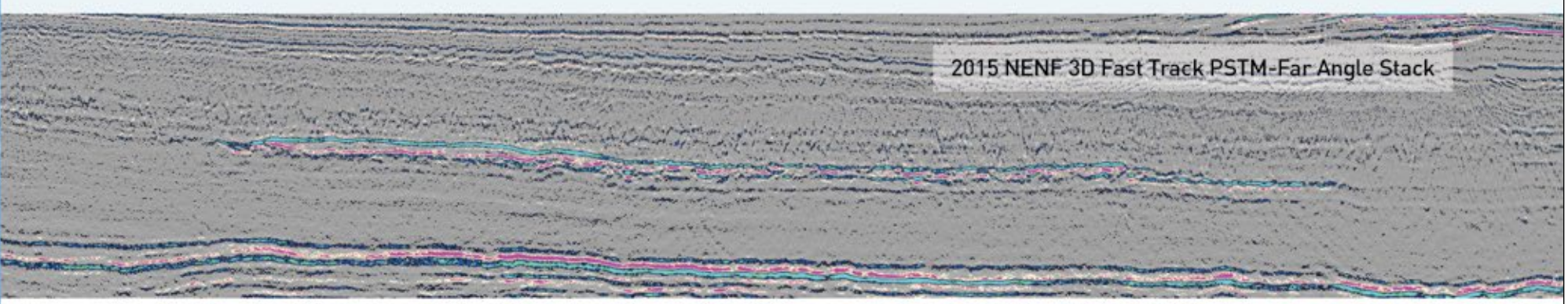

POLICYWATCH

STEM Education For Tomorrow's Petroleum Workforce

By EDITH ALLISON, Geoscience and Energy Policy Office Director

Only a short time ago, many in the oil and gas industry were concerned about the potential shortage of workers needed for a growing industry and a wave of retirements.

Obviously, the demand for petroleum geologists and other oil and gas industry professionals has since dropped. However, we know it will go up again, and when it does, concerns about having technically qualified workers will return.

ALLISON

Two recent studies highlight the challenges to getting a degree in science, technology, engineering and math (STEM) – potentially part of our industry's workforce concerns.

Petroleum geology has special educational and occupational demands, but generally follows trends that affect all STEM careers.

Most federal data does not differentiate geology from other STEM subjects, so this column will quote data on college and university education concerns across all areas.

The American Geosciences Institute does track geoscience education trends, though. At the end of this column is their snapshot of employment choices for 2014-15 geoscience graduates.

A few statistics from the National Academies of Science (NAS) help define the problem:

- There is great interest in STEM careers: In 2010, nearly 40 percent of entering students at two and four-year postsecondary institutions indicated an intention to major in a STEM subject.
- However, about one-half of students with the intention to earn a bachelor's degree in a STEM subject and more than two-thirds of those intending to earn an associate's degree in a STEM subject fail to earn these degrees within six or four years, respectively.
- The completion rate is lower for STEM students than for students in many other fields, which raises questions about the quality of the educational experiences for STEM students.

Other studies, including a 2014 study by IHS for the American Petroleum Institute, have shown that women and minorities will occupy a larger share of the future petroleum workforce. These underrepresented groups are highlighted in the studies discussed below.

Two recent reports help define the STEM student population, as well as obstacles for students, especially minority and non-traditional students, seeking STEM degrees. (Non-traditional students may be older, working full time, a single parent or a transfer from a community college.)

The reports also recommend ways that academic institutions, federal and state agencies, and disciplinary societies such as AAPG can help aspiring STEM students get a degree.

- The 2015 report, "Revisiting the STEM Workforce: A Companion to Science and Engineering Indicators 2014" by the National Science Board (NSB), finds that there are multiple pathways to a STEM career, and particular roadblocks for minority and non-traditional students.
- "Barriers and Opportunities for Two-Year and Four-Year STEM Degrees: Systemic Change to Support Students' Diverse Pathways" (January 2016, Board on Science Education and Board on Higher Education and the Workforce of the National Academy of Sciences, NAS).

> **The completion rate is lower for STEM students than for students in many other fields, which raises questions ...**

The study committee's premise was that "all students who are interested in a STEM credential should be: enabled to make an informed decision about whether a STEM degree is the right degree choice for them; afforded the opportunity to earn the degrees they seek with a minimum of obstacles; and supported by faculty, advisers, mentors and institutional policies ..."

The NAS report identified some of the barriers to achieving a STEM degree:

- The culture of STEM workers and industries views student ability as inherent or natural and thus not open to improvement. This may be a barrier to underrepresented groups.
- The use of gatekeeper courses, such as introductory math or science with highly competitive classroom environments, discourage women and minority students.
- Universities' inflexible rules for accepting transfer credits increase the time and cost of getting a STEM education. The NAS report quotes data showing that about half of STEM graduates attended a community college at some point and need to transfer credits.
- STEM degrees may take longer and therefore cost more because of the need for developmental courses, tight course sequencing, limited availability of courses and differential pricing of STEM courses by some universities.
- States that reward universities based on graduation rates discourage universities from accepting non-traditional students, who might take longer to finish.

The report recognizes that disciplinary societies such as AAPG contribute to the quality of STEM education by:

- Improving teaching by providing resources such as peer-reviewed journals, publications and courses to faculty.
- Supporting student chapters that build community among members, connect them to STEM professionals and develop disciplinary identity.
- Providing students with technical conferences, scholarships, career guidance and networking opportunities.

The reports recommend that:

- Academic departments can and should improve their effectiveness by adopting teaching innovations, and providing

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individualized advising and mentoring, undergraduate research or internships and informal student-faculty interaction.

- Academic institutions, states and federal policymakers should better align educational policies with the range of student goals.
- There is need for additional monitoring, data collection, assessment and research into the pathways to STEM careers and the risks and challenges to students.
- Accrediting agencies, states and institutions should improve the transfer process for students.
- Institutions of higher education, disciplinary societies, foundations and federal agencies should better coordinate their STEM support strategies, programs and policies.

A final note: The American Geosciences Institute (AGI), an association of about 50 geoscience associations including AAPG, recently released the results of its latest (2014-15 academic year) student exit survey.

One (perhaps not unexpected) result is that for the first time since the survey started in 2008, the environmental services industry hired more graduates with a bachelor's degree than the oil and gas industry did.

The oil and gas industry continued to be the dominant employer for geoscience master's degree recipients, and graduates with a doctorate primarily went to work in academia.

PROTRACKS

YPs Urge Unemployed to Persevere

By JONATHAN ALLEN, MEREDITH FABER, YP Committee Co-Chairs, and RYAN LEMISKI, YP Committee Vice Chair

As we're all aware, the oil and gas industry is currently in the middle of a downturn. This isn't the first and it won't be the last.

The downturns of the '80s and '90s saw large numbers of geoscientists not only leaving the oil and gas industry, but never returning.

This has resulted in the well-documented bimodal age distribution with a disproportionally low number of mid-career professionals sandwiched between larger populations of young professionals and more senior members of the industry.

The Great Crew Change, as it is commonly called, has been aggressively addressed by many companies through recruitment, mentorship and training programs. However, current business conditions threaten to stall or even reverse this trend.

Companies are severely cutting back on exploration programs and capital budgets and, in an effort to increase cash flow, have reduced the size of their workforce, in some instances significantly.

The Plight of YPs

Young Professionals (YPs) make up a significant percentage of the geoscientists within the oil and gas industry and are feeling the pain of the current downturn.

It's hard not to take being laid off personally, especially if this is your first job and you are early in your career.

There have been and will continue to be a number of technically adept, hard-working people who will be let go in the current downturn, through no fault of their own. Some will quickly find another job in the industry; more will be unemployed for a significantly longer period; others will leave the industry for other opportunities.

For our members who find themselves between jobs, the YPs would like to urge them to stay involved with AAPG. We are in the middle of and are starting several initiatives and programs, and we need dedicated members to lead and move these projects forward.

It's important to remember that in difficult times for the industry, you don't have to be employed in order to add value.

Participating in AAPG and local geological societies gives our members opportunities to stay connected with the industry and network with other members.

Your continued involvement and volunteerism may just be what lands you that next interview or secures your next job. We're going to need talented geoscientists when the price of oil rebounds and companies increase activity.

To the Still Employed

For our members who are still employed, we'd like to issue a call to action.

Although many of us are not in a position to offer one of our laid-off colleagues a new job, we can offer support. Job loss can take a profound toll on mental health.

In early December 2015, the CBC reported that oil patch layoffs have resulted in a 30-percent increase in the suicide rate in Alberta, Canada. A friendly phone call, text or email, or extending an invitation to attend a local networking event, can mean a lot to someone who may be struggling with their current career situation.

Make yourself available as a resource for those who may be in need and, as always, if you or someone you know is suffering from anxiety or depression, seek out the aid of a counselor or mental health care provider.

Got a question for the YPs or want to get involved with the local YP Chapter in your area? Visit us online at aapg.org/youngpros or connect with us on Facebook (search AAPG Young Professionals Special Interest Group), Instagram or Twitter (@aapgypsig).

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Historical Highlights is an ongoing EXPLORER series that celebrates the "eureka" moments of petroleum geology, the rise of key concepts, the discoveries that made a difference, the perseverance and ingenuity of our colleagues – and/or their luck! – through stories that emphasize the anecdotes, the good yarns and the human interest side of our E&P profession. If you have such a story – and who doesn't? – and you'd like to share it with your fellow AAPG members, contact Hans Krause at historical.highlights@yahoo.com.

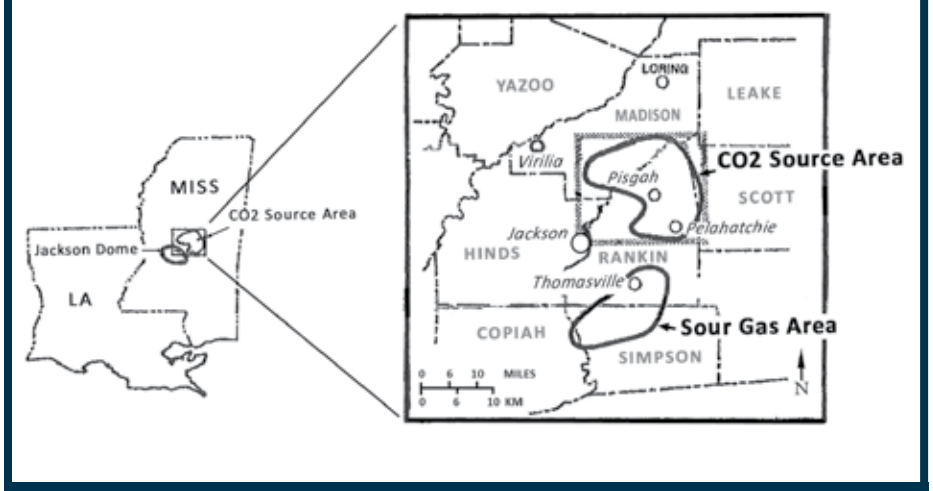

Figure 1 (left) – Regional map showing the interior salt basins and associated structural features. Figure 2 – Location map of Jackson Dome with high concentrations of CO_2 in Madison and Rankin Counties, Miss.

The History of Central Mississippi's Naturally Occurring CO_2 Fields

By KEITH BOWMAN

The largest naturally occurring CO_2 accumulation east of the Mississippi River is currently under exploitation northeast of Jackson, Miss.

Jurassic age sandstones (Norphlet and Haynesville) at depths of 14,000 to 18,000 feet produce food grade CO_2 for tertiary operations in Mississippi, Louisiana and southeast Texas. Three trillion cubic feet (TCF) of sweet CO_2 has been produced northeast of the Jackson Dome area with an additional 4 TCF proved.

Smackover carbonates and sandstones in the equivalent depth range could also contribute an additional 5-7 TCF; however, H_2S concentrations of 2,000 to 7,000 ppm are common in Smackover reservoirs.

These Jurassic reservoirs were sourced during Late Cretaceous time with the piercement of an igneous intrusion referred to as the Jackson Dome.


BOWMAN

John Keith Bowman is the enhanced oil recovery manager for Tellus Operating Group. He began his career with Sun Oil Company as a geologist in Lafayette, La., and Dallas in 1987. He later joined Petro Hunt, then Denbury Resources in Plano, Texas, where he was instrumental in developing Denbury's natural occurring CO_2 source in Mississippi along with tertiary design in Denbury's southwest Mississippi fields, and he was later responsible for evaluation and recommendation of tertiary candidates in southeast Texas and Wyoming in conjunction with CO_2 source identification. He joined Tellus Operating Group in 2012, where he is responsible for tertiary development and monitoring of TOG's producing CO_2 fields, along with identification of CO_2 source opportunities and additional fields with tertiary application.

Early Exploration History

The interior salt basins of east Texas, north Louisiana, and south-central Mississippi proved prolific for hydrocarbon generation and entrapment of large Jurassic age oil and gas pools (figure 1).

Significant Smackover and Buckner age oil discoveries in southern Arkansas and northern Louisiana during the late 1930s to the early 1950s helped push the Jurassic wildcat activity into central Mississippi in the early 1950s.

This area, with down-to-the-basin faults and salt-supported, four-way closures served as obvious areas to continue the Jurassic exploration trend. The Lower Smackover formation is one of the Gulf Coast Interior Basin's major source rocks. The Upper Smackover carbonate play continues to be the most prolific carbonate reservoir play in the interior salt basins.

Before the 1950s, the oil industry was limited by the quality of seismic data that could be imaged due to poor reflectivity when recording below 13,000 feet.

Additionally, the thick fluvial deposits of the Cotton Valley sands above the Smackover section also hampered seismic data quality in this area. As low-fold common depth point (CDP) seismic data became available in the late 1950s, large deep Smackover structures were identified on 2-D seismic lines in Madison, Rankin, Scott and Yazoo counties in central Mississippi.

Early drilling of these structures identified an area in Rankin and Madison Counties as having highly pure CO_2 in Jurassic sandstones and carbonate reservoirs. This CO_2 sweet spot is specific to the northeast flank of the large volcanic feature known as the Jackson Dome.

Four wells drilled in the early 1950s helped to define this CO_2 play. In 1950 and 1952 Conoco drilled the Cameron No.1 and Lee No.1, respectively, on the Virlilia anticline along the Madison/Yazoo county line. These more than 14,000-foot tests found the Smackover carbonates with porosity and permeability, but the drill stem test produced H_2S and "non-burnable CO_2 gas."

In 1951, Lion Oil drilled the Denkmann No.2 on the Pisgah anticline in Rankin County. This more than 16,000-foot test discovered a 260-foot section of Norphlet sand with a 220-foot productive section that tested sweet CO_2.

Shell would later use this test as the show well for their 1977 South Pisgah sweet CO_2 discovery. In 1953 Loring Field was discovered by Carter Oil Company in northern Madison County. Carter Oil found Smackover Sandstones productive with 48-degree gravity condensate and a gas stream composed of 75-percent CO_2. This two-well field ultimately produced 1 mmbo and 50 bcfg, according to state records.

Standard Oil acquired Carter Oil in 1960. The southern limits were defined in the late '60s by Shell's exploration efforts on the Pelahatchie anticline, finding CO_2 concentrations as high as 65 percent (figure 2).

* * *

Approximately 15 wells were drilled in these four counties during the 1960's with most drill stem tests producing varying quantities of CO_2, H_2S and minor amounts of hydrocarbons.

With improved seismic resolution came increased interest in the area, with Chevron and Texas Pacific prospecting north of the Lion Oil test along the 20,000-acre closure now known as the Goshen Springs anticline.

Chevron's 1963 attempt, whose surface location is now located under the Ross Barnett Reservoir, a recreational lake on the Madison-Rankin county line, blew out upon entering the abnormally pressured section just below the top of the Buckner carbonates and was junked and abandoned. This test would later serve as the seismic tie that would confirm an additional undrilled Norphlet structure now known as Dri Ice Field.

In 1967, Chevron's second test, the Cox No.1 discovery well for Goshen Springs Field, logged more than 400 feet of productive Norphlet sand containing 99 percent sweet (food grade) CO_2 (figure 3). Additional formations logged with significant CO_2 volumes were the Smackover, Main Buckner and Haynesville sandstones.

During the same year, Texas Pacific Oil (acquired by Sun Oil Company in 1980) drilled the Yandell No.1 on a southwest satellite structure off the Goshen Springs anticline and was given the field name "Gluckstadt" after finding food grade CO_2.

The Gluckstadt name came from the nearby community settled by German Catholic families in Madison, Miss. in 1905. (This German name translates to "Lucky Town" in English.)

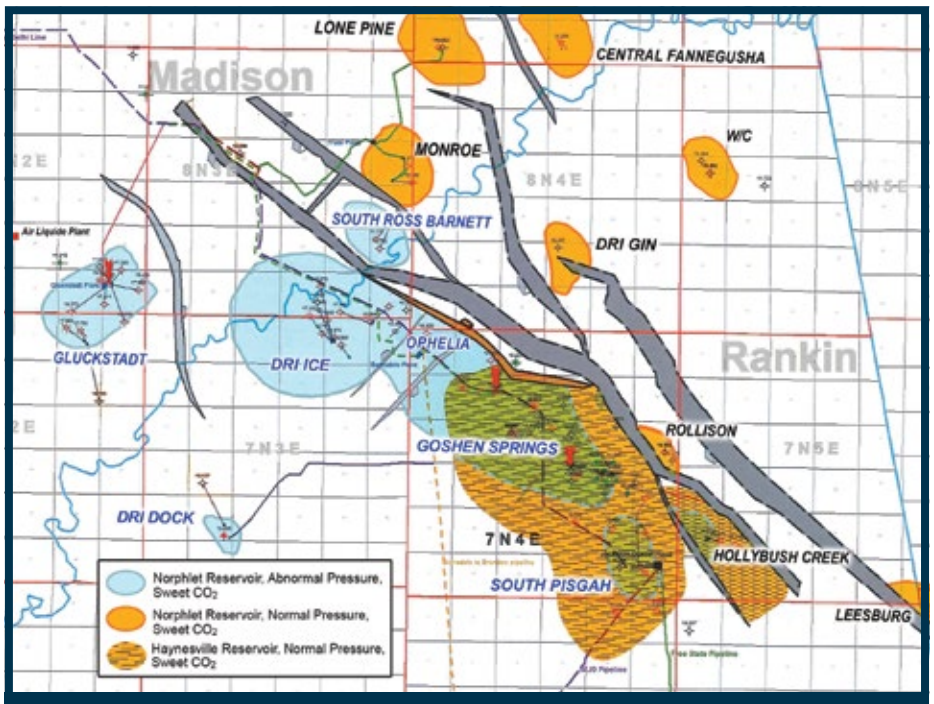

Figure 3 – Jackson Dome Sweet CO_2 fields listed by reservoir and pressure.

Continued on next page

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This discovery logged hundreds of feet of CO_2 in the abnormally pressured Norphlet Sands. These three wells, Denkmann No.2, Cox No.1, and Yandell No.1 identified a very large Norphlet sand pile or erg rich in sweet CO_2 (denoted by red arrows in figure 3).

These drilling results also showed the Smackover formation to be heavily dominated by quartz-rich clastics and isolated carbonates.

By the late 1960s, with the area's poor hydrocarbon exploration success and limited CO_2 market, exploration moved southeast along the Smackover trend into Clarke, Jasper and Wayne counties where the carbonate ramps redeveloped and Smackover hydrocarbons were found and produced.

Beginnings of EOR: Shell Oil's Operations

West Texas Permian Basin CO_2 enhanced oil recovery (EOR) began in Scurry County, Texas in 1972. Shell Oil's knowledge of the Jackson Dome area and the company's asset base in southwest Mississippi were catalysts for EOR development on Mesozoic sandstones of Tuscaloosa age at Little Creek Field in Lincoln and Pike counties.

If EOR proved economic, Shell's operated Mallalieu and Olive Tuscaloosa fields would follow Little Creek development. In addition, Shell's operated fields of Weeks Island and East Bay Fields in south Louisiana would also be tested as EOR candidates.

Chevron had leased most of the crestal Goshen Springs acreage and had more than 20 possible well locations (figure 3).

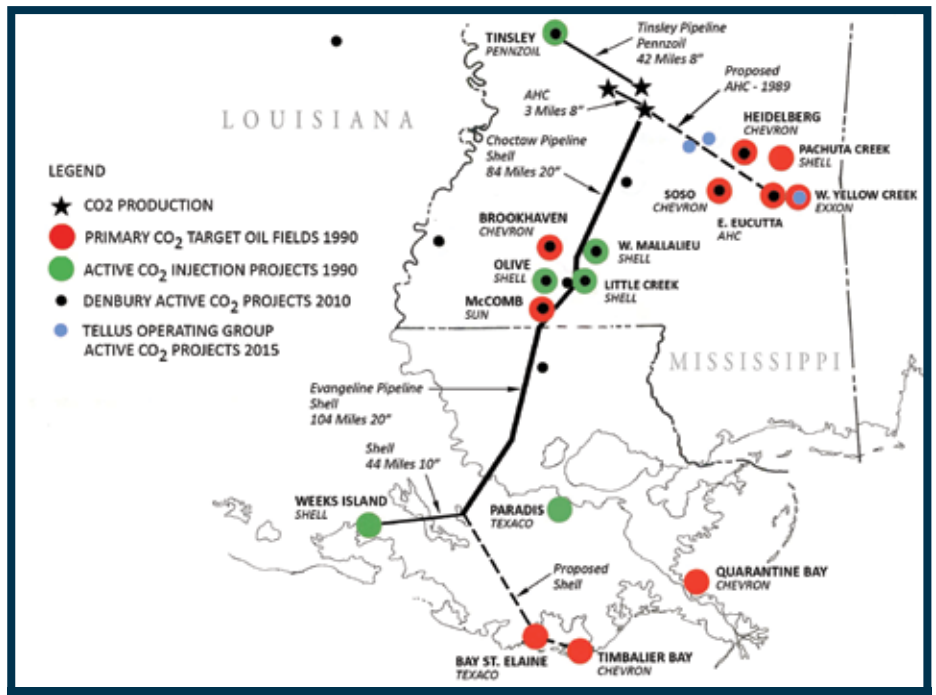

Figure 4 – Identification of "tier one" CO_2 candidates in Mississippi and the major operators in 1990. Currently 15 fields are undergoing CO_2 operations; 12 are operated by Denbury and three by Tellus Operating Group.

In the mid-1970s, Shell's leasing concentrated south and north of Chevron's leasehold acquiring over 50,000 acres over nine proposed CO_2 prospects.

Average terms of these CO_2 leases were 10 years at $35 per acre and burdened with a one-eighth royalty. Shell drilled five structures finding CO_2 in all and delineated South Pisgah and Hollybush Creek Fields' sweet CO_2 reservoirs with 10 wells during the late 1970s.

Estimated sweet CO_2 reserves of 1 TCF were booked with 80 percent of the reserves in the normal pressure Haynesville sands at 15,000 feet. Cumulative deliverability rates of 250 million cubic feet of gas per day (MMcfpd) of CO_2 were banked for Little Creek and Weeks Island testing.

Shell's internal estimates for additional company-operated Gulf Coast CO_2 EOR properties would require an added deliverability of 500 MMcfpd of CO_2.

These volumes would be supplied from the development of Lone Pine, Central Fannegusha and the Leesburg discoveries (figure 3).

Pipeline construction to deliver the CO_2 from the Jackson Dome source area to southwest Mississippi and continuing into south Louisiana's Weeks Island Field was completed in the early '80s. A total of 188 miles of 20-inch pipeline was laid through Mississippi to Donaldsonville, La., followed by a 44-mile, 10-inch line to Weeks Island.

Completion of Little Creek unitization in 1981 was followed by Little Creek EOR in 1982. In conjunction with Shell's EOR efforts in Mississippi, Pennzoil had drilled a Section 16 well in Goshen Springs Field in 1982 and laid a 42-mile, 8-inch pipeline to Tinsley Field, the second largest oil field in the state.

Chevron's Cox well, drilled in 1967, finally went online in 1983 and also supplied CO_2 to Tinsley Field (figure 4).

Generally low oil prices in the late 1980s and '90s limited EOR profitability. With the continued divestment of domestic oil properties by the major U.S. oil companies during this era, EOR from CO_2 in the southeast and specifically Mississippi was reduced to less than 3,000 BOPD.

Lost Decade of the '90s

Charles H. "Chuck" Simpson arrived on the scene in 1990 from Baton Rouge, La., and aggressively promoted a new pipeline from Goshen Springs field that would serve as a CO_2 source for the prolific fields located in southeast Mississippi.

Fields targeted were Chevron's Heidelberg, Exxon's West Yellow Creek, Shell-Texaco's Pachuta Creek, and Amerada Hess's Eucutta Field. Both Chevron and Amerada Hess had internal studies transporting CO_2 to

See **Pipeline**, page 26

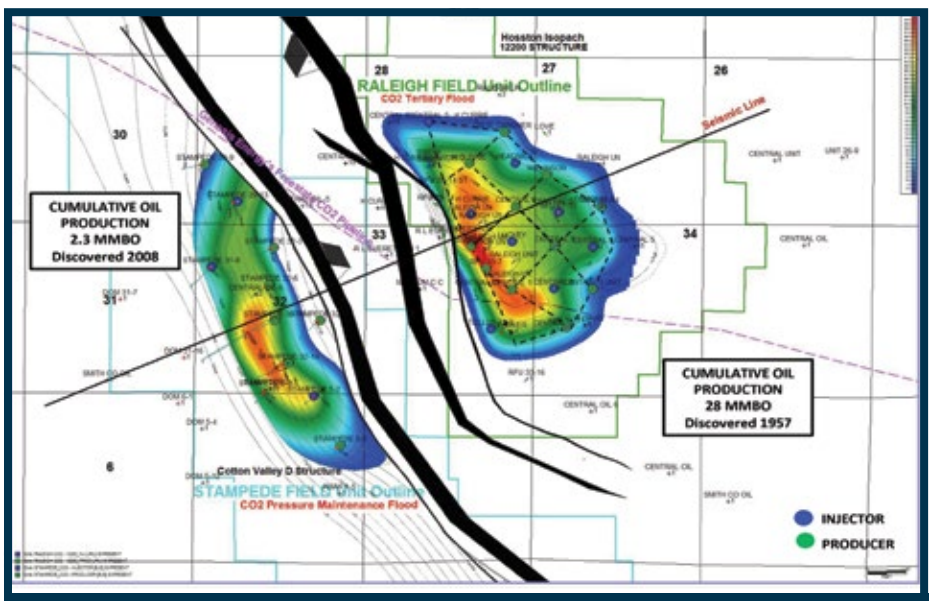

Figure 5 – Tellus tertiary properties in Smith County, Miss.

Pipeline
from page 25

southeast Mississippi. Amerada Hess had outlined their proposed CO_2 pipeline into southeast Mississippi per 1989 correspondence (figure 4).

Simpson acquired new leases (10-year) under the entity of Cherokee Associates and took assignment of some Texaco leases in the two-well field of Goshen Springs. Goshen Springs at the time was estimated to contain more than 8,000 acres of productive area with recoverable reserves of food grade CO_2 of 1.2 TCF.

Simpson's group, Pisgah Partners, through Magna Carta LLC, controlled more than 4,000 acres over the productive limits of the field. In 1991, Simpson purchased the shut-in Cox No.1 from Chevron and by 1993 sold CO_2 to Pennzoil at their Tinsley field. In 1996, Simpson sold the Cox and operations to Pennzoil and retained a working interest of 50 percent.

Low oil prices in the late '90s barred any interest in a CO_2 pipeline to southeast Mississippi (figure 4). In 1997, Shell elected to abandon its tertiary recovery efforts in Mississippi and sold its CO_2 properties to Air Gas Inc. for specialty gas marketing and dry ice manufacturing. In early 2000, Simpson negotiated lease extensions through 2005 in Goshen Springs from one of the largest mineral owners in Madison and Rankin counties.

Golden Age: Denbury and Hidden Treasuries

In February 2001, Denbury Resources Inc. purchased the CO_2 production and pipeline assets from Air Gas Inc. for $42 million. This acquisition included the same properties that Shell Oil had sold to Air Gas Inc. five years earlier.

Denbury purchased 10 producing wells, three undeveloped discoveries, a 182-mile pipeline to Donaldson, La. and other related infrastructure. At the date of purchase, sweet CO_2 proved developed producing (PDP) reserves were estimated at 800 BCF with a current production rate of 90 MMSCFD. Fifty-five percent, or 50 MMSCFD of this CO_2 production stream was sold to commercial users and 40 MMSCFD was purchased by Denbury.

Denbury had purchased Mississippi's first CO_2 flood, Little Creek field, in 1999 from J.P. Oil Company Inc. This acquisition marked Denbury's first venture into CO_2 tertiary operations.

Denbury's acquisition of Simpson's interest in the Goshen Springs Field further consolidated their control of Jackson Dome's CO_2 reservoirs.

At the end of the first quarter of 2003, with compression facilities updated, deliverable rates of 250 MMSCFD were possible; with the completion of two new CO_2 wells, PDP reserves of approximately 1.6 tcf were booked.

Over the last 14 years, Denbury has produced over 3 TCF of natural sweet CO_2 from approximately 45 wells with nearly a billion dollars invested in CO_2 production. To date, 11 CO_2 fields have been developed and 10 are currently producing.

Denbury's discoveries at Dri Ice, South Ross Barnett, Ophelia and Monroe Fields added an additional 3 TCF of recoverable reserves. Dry holes have been limited to four because of 3-D seismic data sets. Remaining PDP reserves are over 5.5 TCF with an additional 2.1 TCF possible. A CO_2 pipeline infrastructure of over 480 miles has been laid for the redevelopment of 11 oil fields within the state of Mississippi.

Cumulative oil production from tertiary operations is over 100 million barrels for the state with an additional 250 million barrels possible under current pricing.

Currently, more than 50 percent of Mississippi's oil production, or 31,000 bbl per day, is from CO_2 tertiary operations.

One factor in Denbury's early success was the understanding of CO_2 deliverability in the abnormally pressured Norphlet reservoir. Production rates of 50 MMSCFD per well have facilitated the average 20-25 mcf per barrel net utilization rate for these Mississippi miscible and immiscible tertiary floods.

Denbury's organic growth in the Mississippi oil patch helped fund their domestic operations into Texas, Montana and Wyoming. A company with total assets of $790 million in the fourth quarter of 2001 ended 2011 valued at $10.2 billion.

In 2010, Chuck Simpson, who had retained a 20-year contract at 20 MMSCFD from Denbury for sweet CO_2 delivery, sold the contract to Tellus Operating Group. Tellus uses this CO_2 for pressure maintenance and EOR projects at its Stampede, Raleigh (figure 5) and West Yellow Creek fields, respectively.

Unfortunately, as Shell experienced in the 1980s, the recent precipitous reduction in commodity prices constrains economic viability of many Mesozoic and Cenozoic CO_2 tertiary floods in the Gulf Coast region. Gulf Coast CO_2 net utilization rates are two- to three-times greater than West Texas net utilization rates.

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The Geophysical Corner is a regular column in the EXPLORER, edited by Satinder Chopra, chief geophysicist for Arcis Seismic Solutions, TGS, Calgary, Canada, and a past AAPG-SEG Joint Distinguished Lecturer.

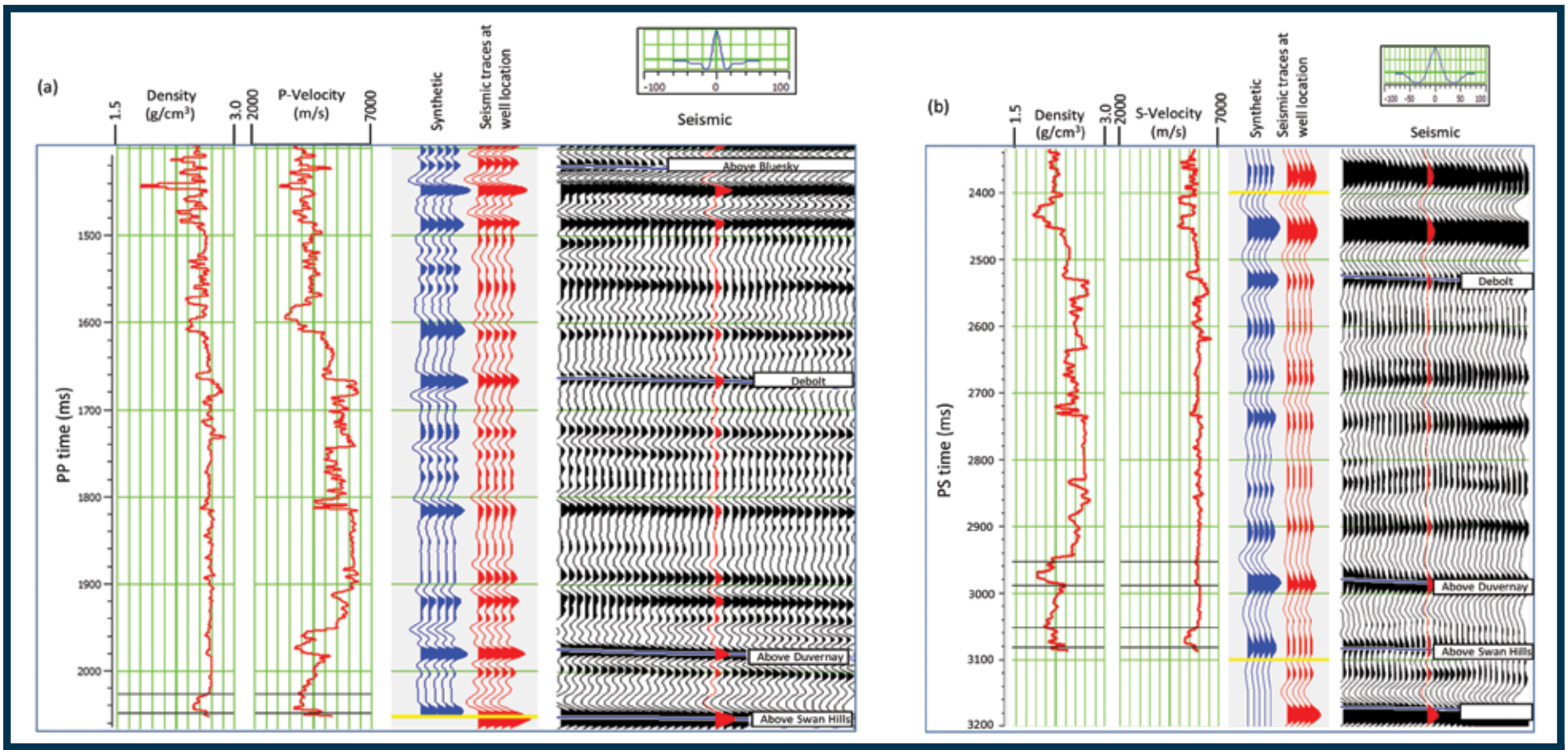

Figure 1 – Well to seismic tie for (a) PP data, (b) PS data. The synthetic traces are in blue generated using the reflectivity from the log curves and the wavelet shown alongside to the right. The red traces are the seismic traces at the location of the well. A good correlation is seen between both the PP and PS data and the log curves. Data courtesy of Arcis Seismic Solutions, TGS, Calgary.

Enhancement of Multicomponent Seismic Data

By SATINDER CHOPRA and RITESH KUMAR SHARMA

Our seismic industry has witnessed many revolutions, starting from refraction to reflection imaging (1919), analog to digital recording (1963), the introduction of the common depth point (CDP) technique (1952) and the transition from 2-D to 3-D P-wave seismic data in the 1980s.

Thereafter the application of repeated 3-D seismic surveys over time helped monitor reservoir properties during the productive lives of different fields. This came to be known as time-lapse or 4-D seismic, and viewed by many as an extension of 3-D seismic technology.

Multicomponent seismic technology was experimented with in the 1960s and '70s, with different types of sources and processing of the acquired S-wave data thereafter. It is considered the next big revolution, though it made its entry slowly and is gradually emerging as a very useful technology.

If we consider some of the challenges that we face with regard to the applied geophysics, we may be able to list them as follows:

1. Distribution of faults and fractures.
2. Understanding of subsurface stress regimes.
3. Description of reservoir rock type and the fluid content.
4. Imaging of the subsurface in complex geological set ups, e.g. deep water, sub-salt or gas zones.
5. Quantitative saturation and pressure changes.

The use of P-wave seismic data alone may not be enough to help us address the challenges stated above, which probably require an improved technology or approach that can bring a shift in the conventional interpretation and, hence, the drilling plans made from that interpretation.

Being three-dimensional in nature, when a seismic wave propagates in the subsurface, it causes the rock particles or fabric to oscillate about their mean positions in different directions.

CHOPRA

SHARMA

The P-wave causes the rock particles to oscillate in the direction of the propagation wavefront.

When a P-wave arrives at subsurface rock interfaces at non-normal angles of incidence, a mode conversion of P-wave energy takes place into two different types, i.e. P to SV and P to SH modes.

Both SV and SH waves cause the rock particles to oscillate perpendicular to the direction of the propagating wavefront. The directions of the SV and SH waves are orthogonal to each other as well.

These three different components of the seismic reflected wavefront can be recorded with sensors that recognize their particle motions (P-, SV and SH).

Geophones used for conventional seismic data acquisition are constrained to respond to just one component, i.e. the vertical P-component.

But the three-component (3-C) geophones have the motion sensing elements arranged in a single casing and are used for recording the 3-C seismic wavefield. Such 3-C geophones are good for recording multicomponent seismic data on land.

Conventional marine seismic data are acquired by using hydrophone streamers towed behind boats. The hydrophones consist of some piezoelectric material that responds to pressure variations in the water caused by the reflected seismic wavefield.

As shear waves do not propagate in water, hydrophone streamers cannot record shear waves emanating from P-wave sources and getting converted at subsurface rock interfaces.

To record shear waves in marine environments, ocean-bottom cable was developed, which can be placed on the sea floor and can capture converted shear waves.

For improving the recorded data quality, a vertical geophone and a hydrophone at each sensor location were summed and came to be known as a "dual sensor technique."

This was followed by upgrading the geophones to three components so that now, 4-C (hydrophone and three-component geophone) technique is successfully used for recording converted shear waves, in addition to the P-wave data.

Thus multicomponent seismic data are now acquired, both on land and offshore areas, processed and interpreted to address many of the challenges listed above.

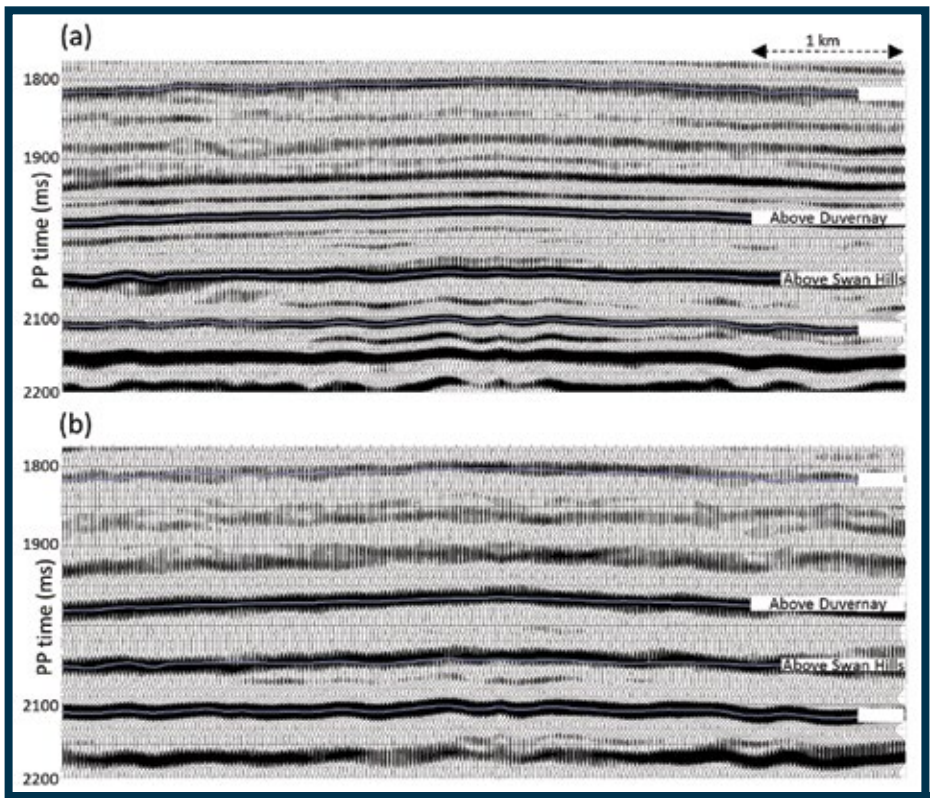

Figure 2 – A segment of (a) PP- data section extracted from the data volume along an arbitrary line in PP time, and (b) equivalent PS- data section extracted along the same arbitrary line. Notice the good correlation of the marked events on both sections, but the frequency content of the PS- data is lower than the frequency content of PP data.

Continued on next page

Continued from previous page

Spectral Balancing of PS Data

In the July 2015 Geophysical Corner, the authors described the joint impedance inversion technique for using PP and P-SV seismic data, which yields P- and S-impedance data. These attribute volumes can be used to derive different reservoir properties.

In this article we discuss how the preconditioning of P-SV (henceforth referred to as just PS) data can lead to more meaningful joint inversion results as applied to 3-D seismic data from the Kaybob area of northwest Alberta, Canada, where the Devonian Duvernay shale formation is an emerging shale liquids play.

Once the 3-D multicomponent seismic data are processed, for carrying out any consistent analysis, the first step is to carry out an accurate PP and PS time correspondence, a process referred to as "registration."

This is accomplished by tying the processed PP and PS data with PP and PS synthetic seismograms respectively, generated over the same range of frequency bandwidth as the input reflection data.

In figure 1, we show the synthetic seismograms generated and correlated with PP (in PP time) and PS data (in PS time). One can notice the lower frequency content of the PS data than the PP data.

In figure 2, we show data extracted along an arbitrary line from the PP and PS data volumes, which again exhibit the different frequency content of the two volumes.

Such differences in the frequency

See **Mismatches**, page 30

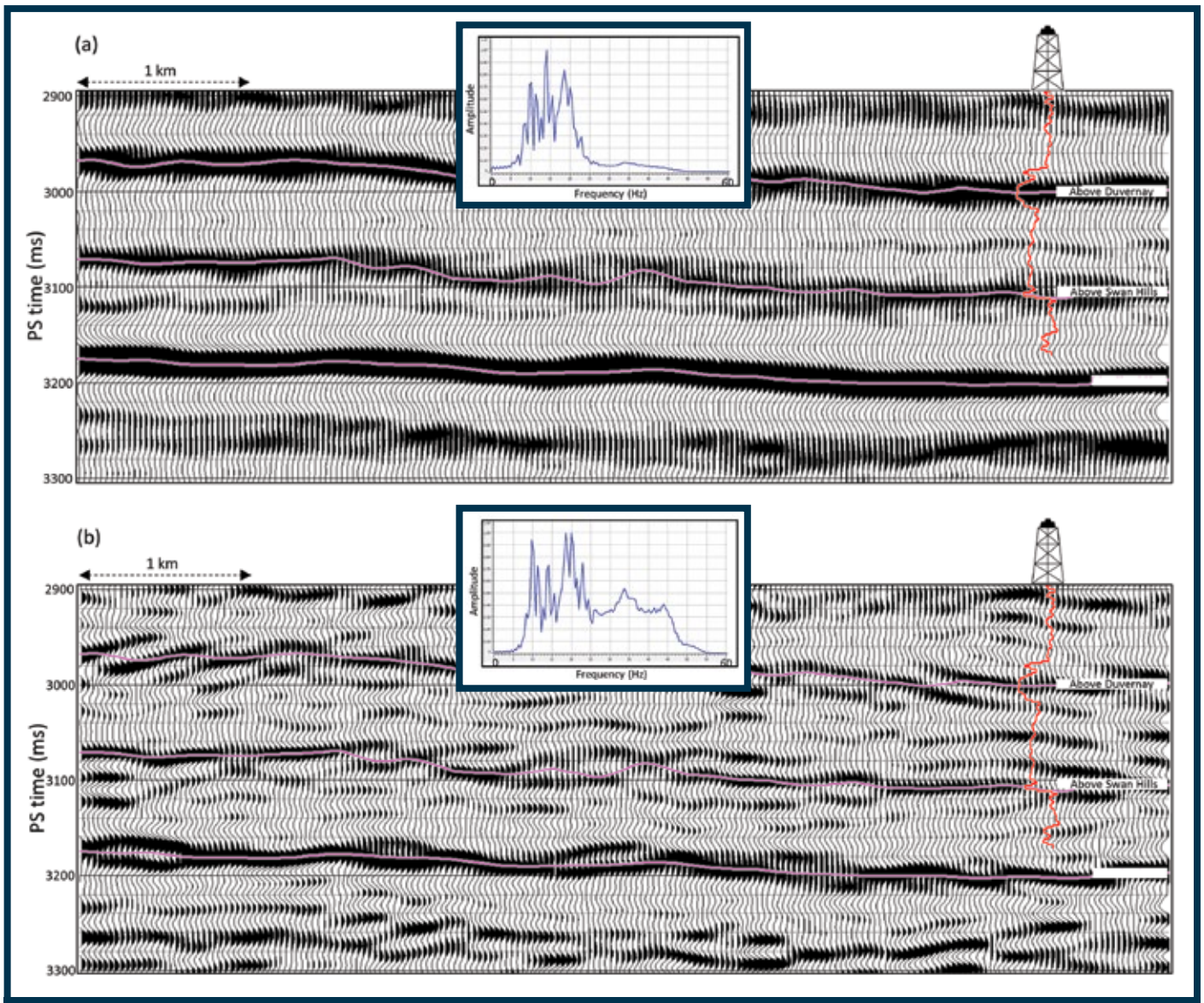

Figure 3 – Segment of a (a) PS-wave seismic section from the Kaybob area in northwest Alberta, Canada, and an equivalent section from (b) spectrally balanced PS wave data volume. Notice the lower frequency content (< 25Hz) before has been enhanced with the frequency enhancement process. The bland zones within the marked horizons seen in (a) show more reflection events which seem to correlate with the impedance log curve overlaid on both sections.

Mismatches
from page 29

content imply differences in amplitude and phase of the PP and PS reflection events, which in turn result in mismatches during registration and thus has a negative effect on the reservoir properties determined therefrom.

If the spectral content of the PS data was somehow balanced with that of the PP data, the problem could be mitigated. For doing this we make use of the *amplitude-friendly* spectral balancing method we described in the March 2015 Geophysical Corner.

In this method, the data are first decomposed into time-frequency spectral components. The spectral magnitude is averaged over all the traces in the data volume spatially and in the given time window, which yields a smoothed average spectrum.

Next, the peak of the average power spectrum is also computed. Both the average spectral magnitude and the peak of the average power spectrum are used to design a single time-varying spectral balancing operator that is applied to each and every trace in the data.

As a single scalar is applied to the data, the process is considered as being amplitude friendly.

In figure 3, we show the application of amplitude-friendly spectral balancing to the PS data. We note the bland reflection zones in between the marked horizons as seen in figure 3a, exhibiting more reflection detail (Figure 3b) that seems to correlate with the impedance curves overlaid on the section.

The overall enhancement in the frequency content of the PS data (in PS time) after spectral balancing can be gauged from the frequency spectra alongside figure 3.

The PS data with enhanced frequency content was next put through the process of registration, wherein the apparent bandwidth further increases. This data is then put through joint inversion which was described by the authors in the July 2015 Geophysical Corner.

In figure 4 we show a comparison of the V_P/V_S sections before and after spectral balancing. As Indicated on the figures, the definition of the many reflection events looks crisp and detailed, which can aid the interpretations made therefrom.

We thus conclude that appropriate spectral balancing of the PS seismic data before carrying out its registration with the equivalent PP seismic data can lead to more detailed and meaningful attribute volumes that are derived, and consequently result in more accurate interpretation.

We thank Arcis Seismic Solutions, TGS, Calgary, for permission to present this work.

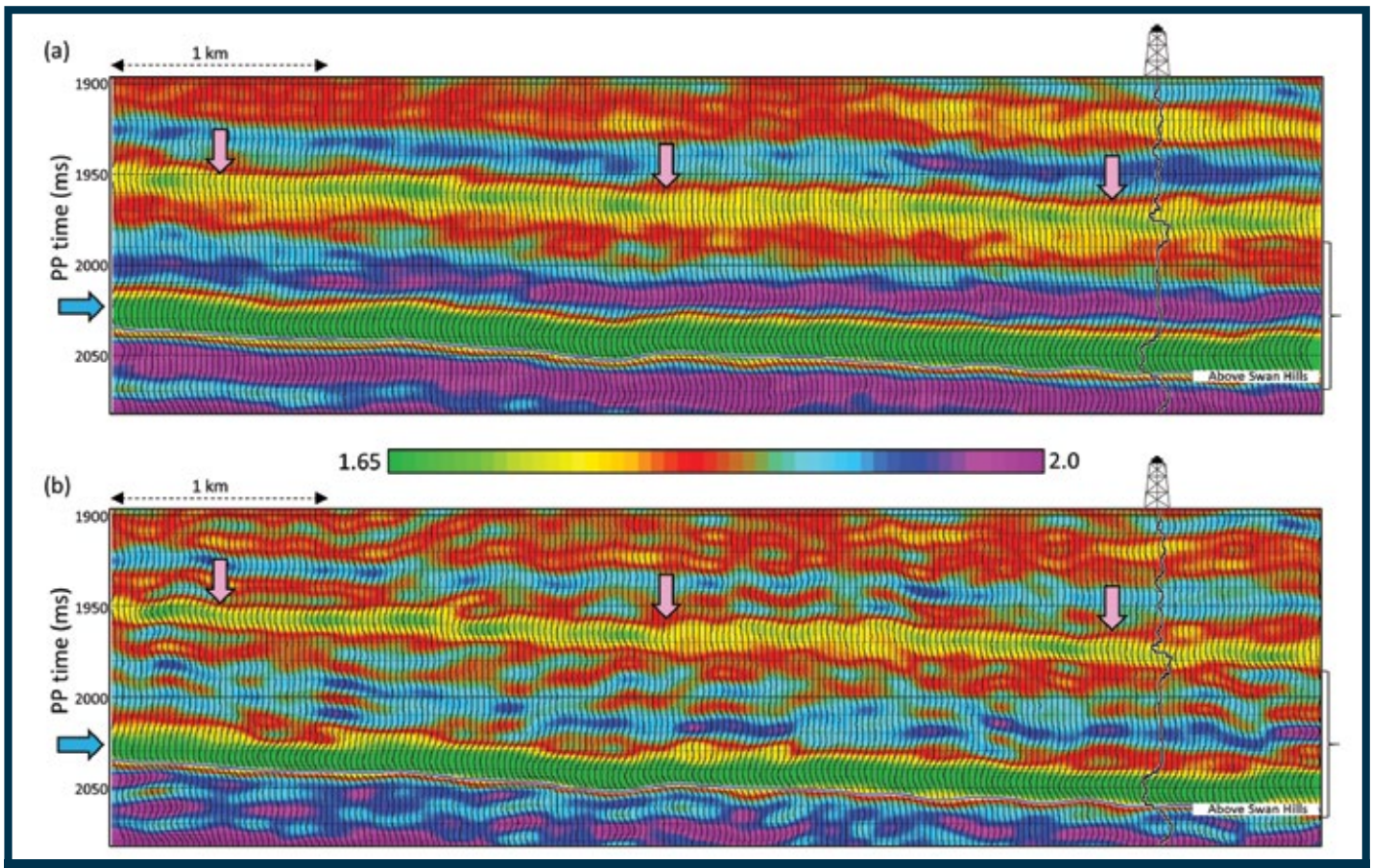

Figure 4 – A portion of a section from VP/VS volume computed using post-stack joint inversion with (a) the PS-wave data as obtained after processing, and (b) using spectrally balanced PS-wave data. Notice the crisp definition of the event indicated with the pink arrows, and the enhanced resolution of the time zone marked to the right with a curly bracket (and in particular the blue arrow to the left).

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Reservoir Analogues from Modern & Turbidite Systems, Tabernas Basin — April 7–10, Barcelona, Spain (with SEG/AAPG ICE)

Sequence Stratigraphy, Facies, Architecture and Reservoir Characteristics of Fluvial, Deltaic and Strand-Plain Deposits — April 30–May 7, Utah

The Lodgepole-Bakken-Three Forks Petroleum System: A Field Seminar for Geologists, Engineers and Operators in Western Montana — May 23–25, Montana

Modern Terrigenous Clastic Depositional Systems — May 31-June 6; September 11–18, Columbia, SC

Deep-Water Siliciclastic Reservoirs — June 13–18, California

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April 3-8, 2016, Santa Barbara, California, USA

The conference aims to bring together professionals from academia, government agencies and industry who are actively involved in pushing the technical limits and application of basin modeling. New ideas are welcomed from R&D scientists (whether they have an academic or industry background), the hardware/software computing industry, exploration business units of the oil and gas industry, or any closely related disciplines, e.g., geochemistry or geothermal industry. Students are also welcome as long as they are able to actively contribute.

The four main goals of this conference are:
1. To share knowledge, experience and opinions across different affiliations in BPSM
2. To identify limitations of concepts, workflows and technologies and to explore new solutions and potential improvements in BPSM
3. To promote awareness that integration is key to solving complex E&P challenges
4. To better understand the subsurface processes for specific areas of interest through case studies

www.aapg.org/career/training/

Named Gifts Make Research Visions a Reality

By APRIL STUART, AAPG Foundation Program Coordinator

What's in a name?

For many students who are recipients of the Foundation's named awards, names mean they are able to secure the funds necessary to pursue cutting edge field research toward a doctorate or master's degree.

Names mean veterans returning to civilian life who want to pursue their college education have the opportunity to complete their undergraduate geoscience degree.

Names mean university geoscience libraries will be able to offer students access to newly released publications, keeping relevant industry information in the hands of aspiring geoscientists.

Names mean undergraduate students and their student associations will be able to attend field camps and buy gear necessary to explore, furthering their experience in the field.

Granting a Legacy

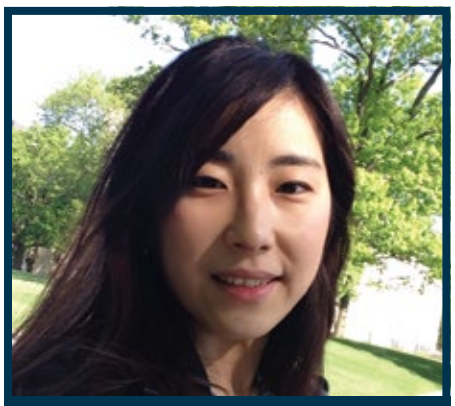
The AAPG Foundation is fortunate to have a roster of more than 100 named funds specifically designated for educational initiatives and targeted to those interested in advancing their knowledge of the geosciences.

With contributions ranging from $13,250 to $50,000, and sometimes more, generous donors continue to build a legacy that will support future generations of geoscientists. That legacy will long support the ability of geoscientists and geoscience students to make their research and educational dreams realities.

Each year, the many named grants through the Foundation's Grants-in-Aid program are distributed to students who have shown excellence in their research proposals.

The application cycle for 2016 recently closed and the Education Awards Committee, led by Chairman Mike Unger, has convened to begin scoring the hundreds of applications received.

Throughout the process, the committee will work hard to match the Foundation's named funds with students whose research focus and university affiliation most closely match each donors' designated purpose and university.



Bohyun Hwang, a graduate student at Ohio State University and the recipient of the 2015 Michael S. Johnson Named Grant.

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Diane L. Reich
In memory of Gerald "Jerry" Markowitz

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

A Grant By Any Other Name …

Many donors contribute gifts in their own names, while others give in honor of friends and colleagues.

For example, long-time supporter Michael S. Johnson, who has a named grant established in his name with designation for a student researcher at Ohio State University, recently made generous contributions to the Foundation for two additional named grants. Mr. Johnson graciously chose to honor two long-time friends.

The first gift established a new grant honoring John W. Robinson, who designated his named scholarship for a student at the Colorado School of Mines.

His second contribution honored William Barrett by adding to his existing grant, which is designated to support a student at Kansas State University.

Gifts like Mr. Johnson's make an enormous difference to students training for a career in geoscience by alleviating some of the financial burden, giving them more freedom to concentrate on research.

There are many ways you can create a gift in your name or the name of a family member, friend or colleague. Grants-in-Aid funds are established with a one-time contribution of $25,000.

Learn more about setting up a fund in yours or someone else's name by visiting the Foundation website at foundation.aapg.org or calling 1-918-560-2644.

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* *

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Research Geologist/Research Chemist (Petroleum Geochemist)

The USGS Central Energy Resources Science Center in Lakewood, Colorado is soliciting interest from qualified individuals for a Research Geologist or Research Chemist with comprehensive experience in organic geochemistry and petroleum geology as applied to the integration of geochemical and geological data in qualitative and quantitative assessments of conventional and unconventional petroleum resources, both domestically and around the world. Successful applicants must meet qualifying education requirements and have demonstrated expertise and substantial experience in organic geochemistry and petroleum geology to formulate and conduct research of fundamental interest and applicability to the Energy Resources Program goals. This work will lead to new hypotheses, concepts, analytical techniques, and a better understanding of geological and geochemical factors that control petroleum generation, migration, entrapment, and alteration. The incumbent is expected to manage an independent research program in one or more of the following areas: 1) controls on deposition and diagenesis of organic-rich rocks as related to petroleum source-rock generation and unconventional reservoir formation; 2) theoretical and experimental studies of the kinetics of petroleum generation; 3) petroleum expulsion, migration, and accumulation; 4) development and application of organic geochemical techniques for petroleum correlation studies (e.g., oil-oil, oil-source, etc.); 5) controls on the molecular and stable isotopic composition of hydrocarbon and non-hydrocarbon gases; 6) secondary alteration of petroleum (biodegradation, thermochemical sulfate reduction, etc.); and 7) applications of organic geochemistry in petroleum systems modeling and basin analysis. The research will likely require proficiency in conducting field and laboratory-based studies, as well as an in-depth understanding of the theoretical foundation of petroleum geochemistry. The position is supported by the research facilities of the Energy Resources Geochemistry laboratories that include: organic extraction and fractionation equipment; gas-chromatography and mass-spectroscopy instrumentation; elemental analysis and source rock pyrolysis (i.e., Rock-Eval); C, H, and N stable isotopic analysis of solids, liquids, and gases; and large-scale (hydrous pyrolysis) and small-scale (sealed tube) pyrolysis laboratories for experimental studies of high temperature and pressure reactions. Candidates must be able to work as part of a multidisciplinary team of geologists, geochemists, geophysicists, and engineers, and to contribute to petroleum resource assessment activities. Excellent writing and oral presentation skills are also required because candidates are expected to publish results of scientific studies in technical journals and USGS publications.

Applications (resume, unofficial transcript, and application questions) for this vacancy must be received on-line via USAJOBS (http://www.usajobs.opm.gov) BEFORE midnight Eastern Time (Washington, D.C. time) on the closing date of this announcement. If you fail to submit a complete on-line resume, you will not be considered for this position. Requests for extensions will not be granted. If applying on-line poses a hardship for you, please speak to someone in the Servicing Personnel Office listed on the announcement PRIOR TO THE CLOSING DATE. For assistance or questions, contact Jessica Hatch at the Office of Human Resources at 303-236-9565 or jhatch@usgs.gov.

Announcement numbers are DEN-2016-0128. This is a full time permanent position (Research Geologist, GS-1350-13/14 or Research Chemist, GS-1320-13/14) with a salary range of $90,779 (Step 01) to $139,457 (Step 10) depending upon qualifications and experience. The closing date for this announcement is March18, 2016.

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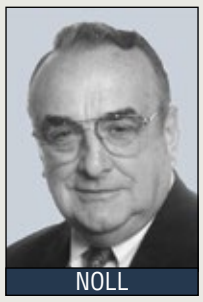

NOLL

Former AAPG Secretary Charles R. "Chuck" Noll has passed away.

He passed away Dec. 24, 2015 in Exton, Pa., less than a month from his 85th birthday.

Noll began both his career and his membership with AAPG in 1955. He worked as a geologist and exploration manager for a number of companies, beginning with Stanolind (now Amoco) in Oklahoma City and eventually formed C.R. Noll & Associates.

He served as AAPG secretary from 1999-2001, received the AAPG Distinguished Service Award and Certificate of Merit in 1995. Noll was also a member of the Division of Professional Affairs and served as DPA president in 1992-93 and received the DPA Distinguished Service Award in 1996.

David William Day Jr., 94
Bakersfield, Calif., Dec. 26, 2015
Alan Paul Hewitt, 82
Midland, Texas, Aug. 19, 2013
Alvin Hoffman, 87
Medicine Hat, Canada, July 30, 2015
Richard B. Lodewick, 81
Placitas, N.M., April 15, 2015
Gerald Markowitz, 61
Bush, La., Jan. 2, 2016
Albert Ross Murchison, 90
Ballinger, Texas, Aug. 24, 2015
Clifton Jerry Nolte, 92
Arvada, Colo., Dec. 3, 2015
Gerald Hugh Smith, 81
Long Beach, Calif., Oct. 20, 2015
Charles W. Spencer, 85
Lakewood, Colo., Jan. 10, 2016
Raymond W. Stephens Jr., 87
Metairie, La., Oct. 20, 2015
Roderick Whitbeck Tillman, 81
Tulsa, Jan. 21, 2016
La Verne Leonard Vigoren, 83
Deadwood, S.D., Dec. 16, 2015
Joseph Leonard Weitz, 93
Fort Collins, Colo., July 22, 2015
Charles Bruce Wilder, 90
Tyler, Texas, June 19, 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.)

DIRECTOR'S CORNER

Attending ACE Is As Important Now As Ever

By DAVID CURTISS

Have you made plans to attend ACE this year?

AAPG's 2016 Annual Convention and Exhibition (ACE) is a dedicated opportunity for our members and other professionals to get together.

And this June we're headed to the great city of Calgary where General Chair Paul McKay and General Vice Chair Jen Russel-Houston and their organizing committee have developed a stellar line up of technical and social activities that will help you be a better petroleum geoscientist.

Once again, ACE will be conducted together with SEPM, the Society for Sedimentary Geology, and is hosted this year by the Canadian Society of Petroleum Geologists (CSPG).

We received a record number of abstract submissions for the 2016 ACE, and the technical program committee, led by co-chairs Laurie Bellman and Ryan Mohr, selected nearly 900 technical talks and posters covering a wide variety of themes:

- Siliciclastics.
- Carbonates and Evaporites.
- Energy and the Environment.
- Geochemistry, Basin Modeling and Petroleum Systems.
- Structure, Tectonics and Geomechanics.
- Unconventional Resources.
- Oil Sands.
- Resources to Reserves.
- Geophysics.

In addition to these technical themes, SEPM will conduct a research symposium on foreland basin drainages and deposition from Monday to Wednesday.


CURTISS

> **Ever since this downturn began I've been writing about the importance of community and sticking together as petroleum geoscientists. There's no better place to do that than at ACE.**

There are 16 short courses offered in conjunction with ACE, ranging from technical subjects, such as "Basin Analysis Methods for Exploration" to "Sequence Stratigraphy for Graduate Students" and "Decision and Risk Analysis for Uncertain Times in the Energy Industry."

Field Trips and Special Sessions

June is a perfect month to get into the field, and we've got 15 opportunities for you to get outside with experts to investigate local geology and better understand the petroleum industry in Alberta.

This year, the organizing committee has also created dedicated field seminars for students and faculty and for young professionals to provide additional opportunities to learn and network with peers.

Naturally, we'll also offer special sessions including the History of Petroleum Geology, exploring how the industry and profession have evolved over the past century. The Discovery Thinking forum returns again this year with its focus on what it takes to turn a discovery into a commercial success. And, Tim Dodson, executive vice president of Statoil ASA, will present the 2016 Michel T. Halbouty Lecture.

A feature of ACE in Calgary is the CSPG International Core Conference, which will run Thursday and Friday after the convention concludes. The theme for the workshop is "Redefining Reservoir: Core Values" and will be held at the Alberta Energy Regulator's Core Research Centre.

Attendees at the core conference will have the opportunity to inspect core from across the globe, including Turkey, Brazil, Germany and North America, and will include rocks from both conventional and unconventional oil and gas plays, siliciclastics, carbonates and evaporites, shales, oil sands and displays related to carbon capture technology.

This truly is a unique experience that will round out your week in Calgary.

Networking Opportunities

Spending a week in Calgary will provide ample opportunities to learn and grow professionally. But don't forget networking, and the organizing committee has you covered on that front, too.

The exhibition is your chance to come up to speed on the newest in technology that will help you be a more successful petroleum geoscientist, meet with service providers, run into friends from the past and make new friends.

The exhibition starts with the Icebreaker on Sunday night and runs through Wednesday midday.

Luncheons, student activities, young professional gatherings and social activities all offer opportunities to expand your professional network.

We'll also have a career center set up if you are currently looking to find a job or looking to hire talented geoscientists.

Ever since this downturn began I've been writing about the importance of community and sticking together as petroleum geoscientists. There's no better place to do that than at ACE.

It's your ability to keep your technical skills fresh, to connect with fellow geoscientists and professionals, and to find inspiration and enthusiasm for your next career move that will propel you forward.

Register before April 19 for our early-bird registration rate.

Make your plans to join us in Calgary from June 19-22 at ACE. Invest in your success.

DIVISIONS REPORT: DEG

The 'Other' AAPG Bulletin: Environmental Geosciences

By JEFFREY B. ALDRICH, DEG President

The AAPG Bulletin is the flagship publication of the AAPG and is a publication we can all be justifiably proud of. How many of you realize that the AAPG publishes a second scientific bulletin that is just as technically excellent with a long history of publishing cutting-edge research?

I am talking about the DEG's Environmental Geosciences (EG), which has been in publication for over 20 years.

Each of the published papers undergo an extensive peer review process, like the Bulletin, and over the years there have been a number of special issues that could have been published separately as a book, but were instead published as an EG issue at no additional cost to members.

These have included the issues on Constructed Wetland Treatment Systems (2008), Geologic Carbon Sequestration (2009), Geophysics for Environmental Investigation (2010) and the upcoming volume on CO_2 Sequestration and Dissolved Methane (2016).

Notable Issues of Environmental Geosciences

Environmental Geosciences has broken the ground with some extraordinary papers over the years such as the 1994 paper by Robert C. Laudon, et. al., "Determination of Flow Potential From Oil Reservoirs to Underground Sources of Drinking Water in the San Juan Basin, New Mexico."


ALDRICH

> **The DEG, through the excellent work of the Environmental Geosciences, has worked to advance the science of environmental geology.**

In this paper the author(s) not only developed a methodology for an Area of Review (AOR) used to this day but demonstrated a (positive) lack of flow from the petroleum reservoir to the overlying aquifer.

Methane identification has been a topic of interest for a long time in the EG and two key papers have set the standard on methane identification practices:

- "Isotopic Identification of Landfill Methane" by Dennis D. Coleman, Chao-Li Liu, Keith C. Hackley and Steven R. Pelphrey in 1995.
- "Identifying the Sources of Stray Methane by Using Geochemical and Isotopic Fingerprinting" by "Frank" Fred Baldassare and Christopher Laughrey in 1997.

The latter concerned investigating sources of stray gas in Pennsylvania before the EPA had identified it as a potential problem.

Deep well injection issues appear to be a topic that "bubbled to the surface" last year but the EG published key papers on the topic with "CO_2 Injection and Sequestration in Depleted Oil and Gas Fields and Deep Coal Seams: Worldwide Potential and Costs," by Scott H. Stevens, Vello A Kuuskraa, John Gale and David Beecy in 2001.

This paper looked at the feasibility of performing enhanced gas recovery, enhanced oil recovery and enhanced CBM recovery in coal basins worldwide, and discussed the challenges associated with the science.

It talked about building on existing technologies from the EOR, storage and CO_2 production industries. This was a paper well ahead of its time.

Also published was "Aspects of induced seismic activity and deep-well sequestration of carbon dioxide" by Joel Sminchak and Neeraj Gupta in 2003.

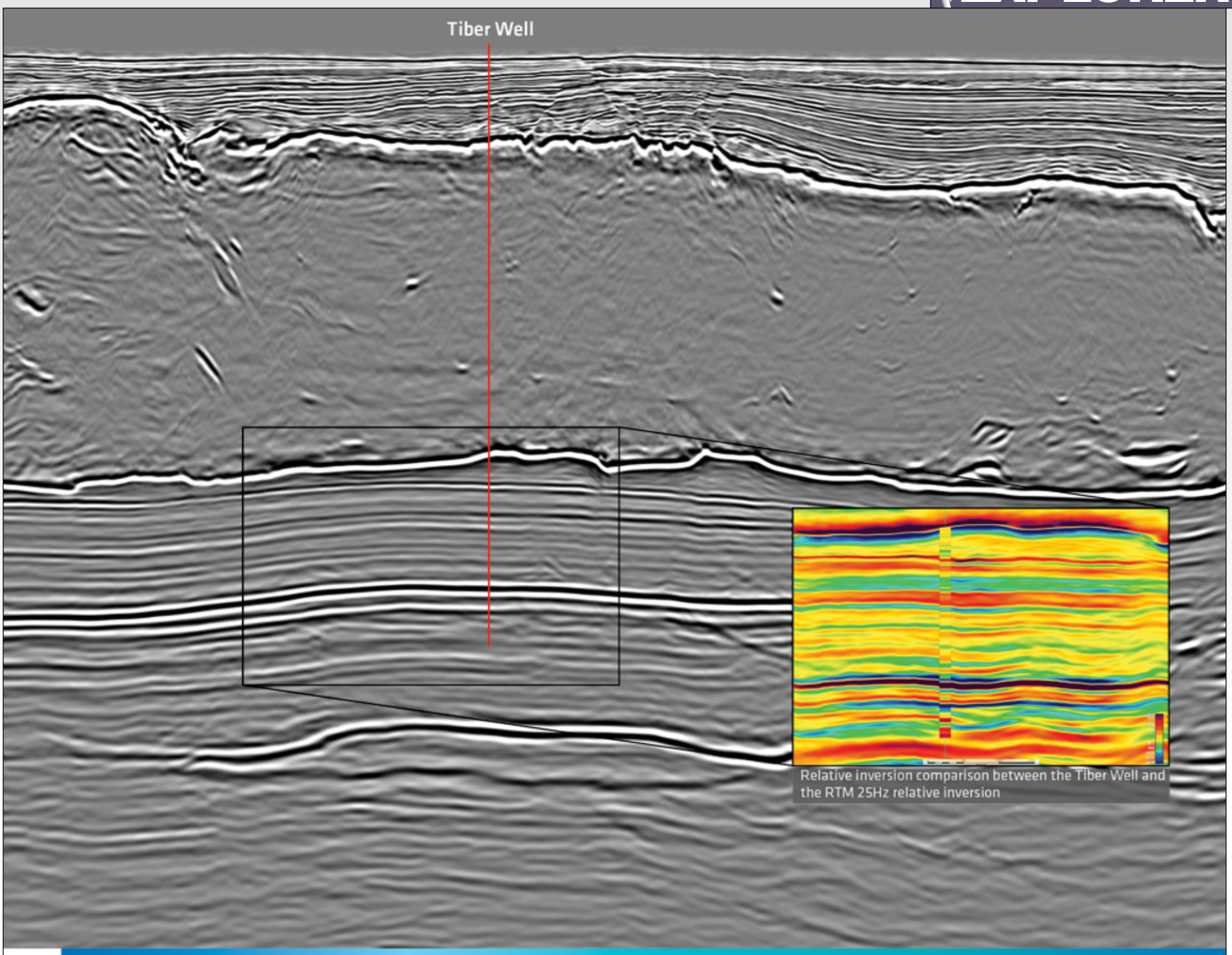
This was at a time when geologic sequestration was just starting to take off as a topic of research. Not only did this study carbon capture and storage but the impact of induced seismicity and how to minimize it.

The DEG, through the excellent work of the Environmental Geosciences, has worked to advance the science of environmental geology. The EG is available to members of the DEG in electronic format.

The DEG also supports the work of environmental geosciences through sponsoring sessions at the AAPG's annual convention.

This year at the Annual Convention and Exhibition in Calgary, Canada, the DEG is sponsoring Theme 3, "Energy and the Environment," with three technical sessions, co-sponsoring the oilsands workshop, and a fieldtrip to the glaciers.

Francois Marechal, the DEG Calgary technical co-chair, and I hope to see you in Calgary.



Relative inversion comparison between the Tiber Well and the RTM 25Hz relative inversion