NOVEMBER 2017 | 100 AAPG ANNIVERSARY

EXPLORER

# Rocks and Rockets

## Commercial space exploration will propel astrogeology to new heights.

*See page 8.*

PRIME PROSPECT

# 2017 Zambezi Delta 3D Survey
## Mozambique


In collaboration with the Instituto Nacional de Petroleo (INP), CGG will commence acquisition of up to 40,000 km² of advanced 3D seismic data over the Beira High in the Zambezi Delta in Q4 2017.

The data will be processed through a state-of-the-art deghosting and broadband imaging sequence, creating PreSTM and PreSDM volumes, including Full-Waveform Inversion (FWI) velocity modeling.

The seismic survey will be complemented by a **JumpStart**™ integrated geoscience program, incorporating gravity, magnetic, well and geological information, designed to accelerate understanding of the petroleum systems in the area.

**The right data, in the right place, at the right time**

Contact us now for further information:

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Vol. 38, No. 11
NOVEMBER 2017

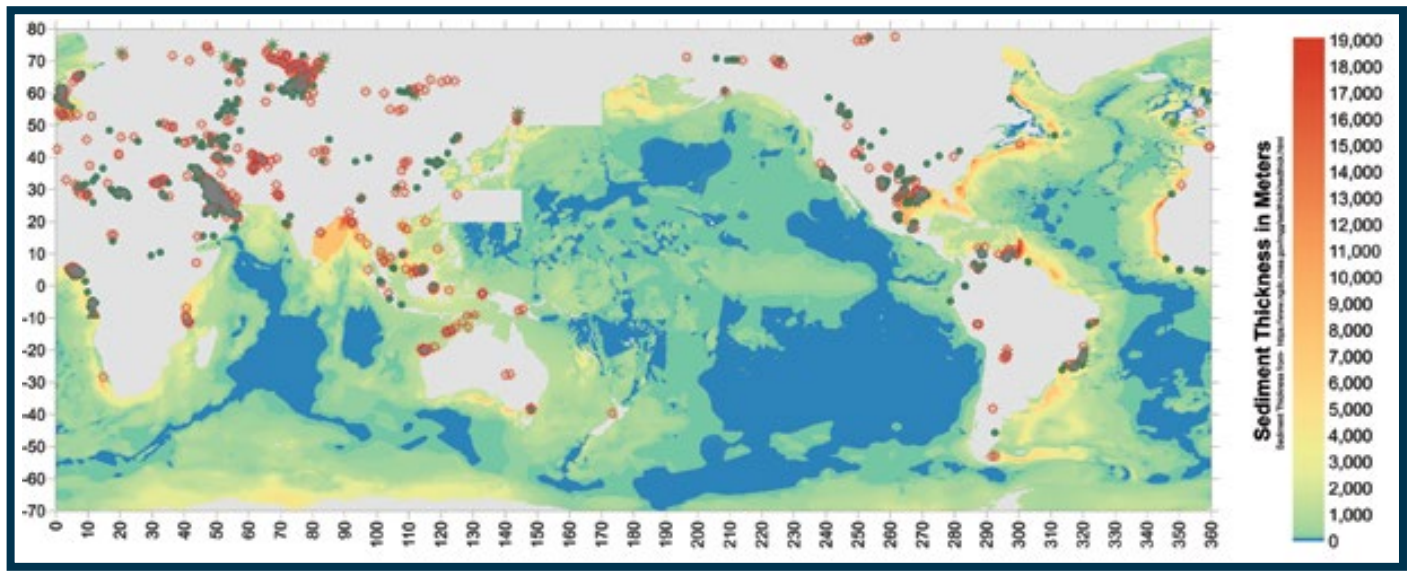
100TH AAPG ANNIVERSARY
EXPLORER

PRESIDENT'SCOLUMN

# Mapping Out an Innovative Future

BY CHARLES STERNBACH

In the United States we celebrate Thanksgiving on November 23. No matter where you are in the world, it is always good to give thanks. I am thankful to organizers of this year's highly successful International Conference and Exhibition (ICE) in London, Eastern, Mid-Continent, and GCAGS fall conference organizers, section and region leadership, our affiliated societies, AAPG's more than 30 committees, divisions, SIGs, TIGs, HOD, publications, Executive Committee, Advisory Committee and headquarters staff. I am thankful to all the volunteers and members of AAPG, other professional societies, and our industry. And I am personally thankful for a profession that allows each of us to work in teams to solve challenging problems while we create energy abundance, prosperity and a better way of life for the world.





STERNBACH

**AAPG members will continue to find energy in both new and old places. Let's continue to go where the energy is as we forge ahead into our second century.**

### The Universal Language of Geoscientists

I have found that some of the best early play concept maps and cross sections are drawn on cocktail napkins. That's because maps are the universal language of geoscientists. Maps can be powerful predictors of prosperity. Maps commemorate creative moments.

I spoke about this at the ICE London Opening Ceremony (video to be posted soon).

In July, we published the global super basins map. This shows the top 25 global super basins. These are the world's richest petroleum provinces with multiple source rocks, many pays and plays, and key infrastructure.

Many more super basins exist, but just the top 25 were shown, referencing a study by IHS Markit. That is a powerful map. It is disruptive. It is a game changing treasure map. Selected basins and technology will be celebrated in our Super Basin Conference March 27-29 in Houston (note that the date has been revised).

Let's look at another map that could have a big impact on AAPG's future.

I have been asked by the news media whether the oil industry will find more oil in new places or in old places, and my reply is "Yes!" to both. Newly released AAPG Memoir 113 discusses giant petroleum fields found in the decade 2000-10 and Bob Merrill and I reviewed giant field patterns over the last 100 years – "The AAPG Century."

A "giant field" is defined as 500 MMBOE. Note that there are about 1,000 giant fields shown by red gas symbols and green oil symbols. This is our past and present. The accompanying map shows sedimentary thickness increasing in yellow and orange areas (from NOAA), hints to where we may be going in the future. Deep, ultra deep and Artic conditions may pose daunting challenges. However, I believe there is room for many more giant fields and AAPG members will find them!

The bottom line: AAPG members will continue to find energy in both new and old places. Let's continue to go where the energy is as we forge ahead into our second century.

Our Executive Committee continues to focus on the AAPG strategic goals: energy-relevant content, member engagement and financial stewardship. To quote leadership guru Jim Collins, who originated the "good to great" terminology, we can never focus "too much" on core goals.

### Creative Thinking Never Goes Out of Style

What skills are needed to get the job done? No surprise here: geoscience and broad science, adaptability, persistence, communication, computer and business skills help. Creative thinking, critical thinking and discovery thinking are critical elements. The most valued skills cannot be rote memorized, but arise out of

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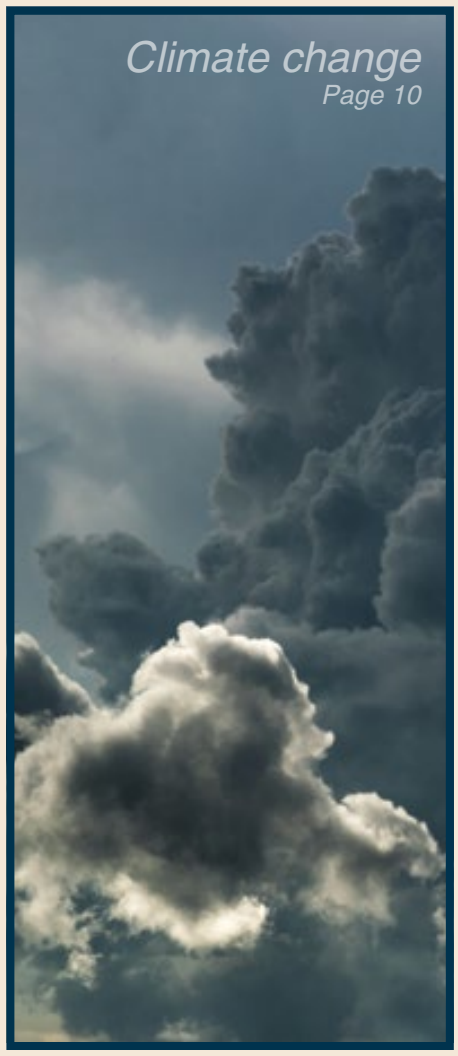
**REGULARDEPARTMENTS**



**ON THE COVER:**

Blue Origin's reusable New Shepard space vehicle lifts off. The ongoing explosion of commercial space flight promises an opportunity-rich future for astrogeology. See story on page 8. Photo courtesy of Blue Origin.

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# APPEX Global Coincides with High Investment Opportunity

By DAVID BROWN, EXPLORER Correspondent

If the recent evidence of an uptick in acquisitions and divestiture activities continues, the next APPEX Global event in London should coincide with many new international prospects in the first quarter of 2018. But if this proves to be correct, the A&D bargain-bin environment won't last much longer, said the event's chair, Mike Lakin of ENVOI Limited in London.

At some point, he said, the effect of the industry's recent downturn will rub away, as has always happened historically when E&P companies return to the market after the slow-down and seek new deals to replace and rebuild their prospective upstream portfolios.


LAKIN

**"The stock markets are littered with dead exploration companies that got caught up in their own excitement and forgot the simple success metrics of proper G and G-led exploration with a spread of assets ..."**

"When the oil price will come back sufficiently for this to happen is anyone's guess, although I believe it will be sooner than most of the so-called experts are now predicting," Lakin said. "If for no other reason than few have ever accurately predicted the commodity price."

The APPEX Global 2018 Prospect and Property Expo will be Feb. 27-March 1 at the Business Design Centre in the Northern London Borough of Islington.

Lakin described the coming expo as an "excellent post-crash opportunity for established players with money or access to capital, whilst entry prices and operating costs remain low." He also noted some "early evidence of funding coming back from the London equity markets to compete with the private equity money that has been one, if not the only source of upstream funding of late."

"The choice of deals with less competition from many other buyers will likely be seen in the near future and questionably the perfect time to invest in E&P, if done wisely and based on sound technical and commercial risk criteria," he said.

### Primacy of G and G

To evaluate potential investments put forward at APPEX, Lakin can already see the early evidence of some E&P companies realigning their geologist and geophysicist teams in preparation for the return to more stable, even buoyant times again.

"Geologists and geophysicists are still the only people that can actually find oil and gas, even if engineers, lawyers, bankers and accountants and entrepreneurs like to think they can," he noted. "Don't get me wrong, all these skills are equally essential to manage, fund, finance, negotiate and legalize this great industry, but finding new commercial quantities of oil and increasingly gas, remains the domain of the subsurface explorationists as clearly evidenced by the many new global plays discovered in the last cycle."

He also foresees the continued growth of advanced exploration technologies, including extra-high-resolution gravity and magnetics and more use of cost effective remote sensing, surface geochemistry and seep analysis to help target the most prospective play areas and enabling improved seismic acquisition, including higher resolution 4-D seismic, to be far more effectively targeted with associates cost savings and reduce exploration risk.

### Back to Basics

Perhaps surprisingly to some, Lakin expects the best A&D opportunities to be found in straight-up conventional oil and gas plays.

"Not many pure resource players appear to have actually made as good returns as the conventional players," he noted.

"The stock markets are littered with dead exploration companies that got caught up in their own excitement and forgot the simple success metrics of proper G and G-led exploration with a spread of assets – with overhead covering production to allow for progressive development of appropriately risked exploration prospects as part of a balanced portfolio – so that the inevitable unsuccessful E&P don't break the company," said Lakin.

"Those who have done this right over time, even through the crash, have survived and some have quietly done exceptionally well," he said, adding, "essentially going back to the future in the same way most of the successful E&P companies have always done it."

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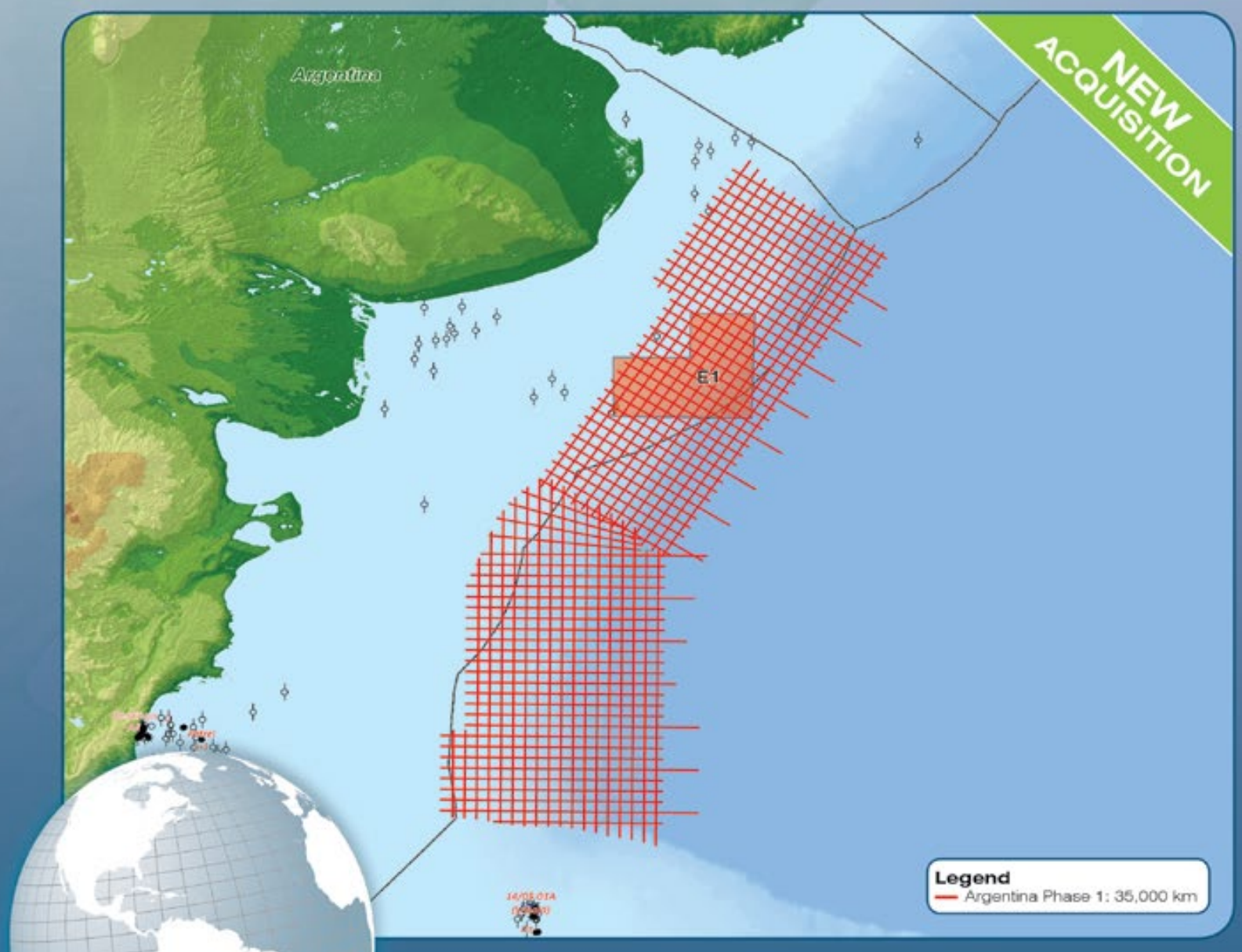
multi-client seismic
ARGENTINA

# Offshore Argentina

## New Multi-Client 2D Seismic Across Unexplored Region




Spectrum has commenced a 35,000 km Multi-Client 2D seismic survey offshore Argentina. The new acquisition program will provide state-of-the-art imaging for the largely unexplored shelf, slope and ultra deepwater basins offshore Argentina.

The survey is being acquired with a 12,000 m streamer and a high fold 25 m SP interval to record data necessary to understand both tectonic architecture and prospectivity in the deepwater basin.

Final deliverables will include broadband PSTM and PSDM, with the first tranche of data expected to be available in Q4 2017.

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+1 281 647 0602

Spectrum

# Geopolitics

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## Global Prospects

That's not to overlook the challenges inherent in global exploration and production.

Geopolitics matter, Lakin said, and the special circumstances of each prospect have to be analyzed carefully. Still, he sees attractive opportunities coming available.

"Plenty (of opportunities) are placed around with many new and underexplored plays areas the world in South America, Africa and Australiasia, but the sheer scale and distance makes anything small challenging, as well as some of the political risk, wars and culture," Lakin observed.

"Conventional America – deserted presently by most traditional funding sources due to the resource boom – along with Europe, are still very prospective in parts where they're not closed down by local anti-frac'ing and emotional bureaucracy," he said.

Good prospects can be found in many other areas of the world as well, Lakin noted, although non-exploration risk and high risk, complex political realities can dampen their attractiveness.

"CIS (Russian Commonwealth) and Asia offer excellent geology but the political – and in many parts also personal risks – can be high. Australia is still an interesting place with much potential and increasing high gas prices, but it remains remote and, for many, an airplane too far," he said. "The Far East is tough due to complex geology and has generally high government takes. Russia and China are still to have their day for most E&P companies due to their political complexities."


*London's Business Design Centre will be the venue for the APPEX Global 2018 Prospect and Property Expo in February.*

## Shrinking the Bubble

In assessing any proposal, operators and investors will do well to stick to the basics and make sure the economics remain manageable where the geological risk is right, Lakin advised.

"The old adage of finding the source rocks first when targeting the conventional plays, combined with the new technologies that can commercially stimulate tight conventional plays. And all managed within modest company overheads covered by production cash flow, and not just debt or equity-market promise," he said.

Lakin questioned the underlying profitability of many unconventional plays, especially with U.S. oil prices hovering around $50 a barrel. He sees an increasing sector concern that the bubble-like quality to resource plays, outside a few secure areas and by the early entrants.

"The bubble has yet to burst, or hopefully simply deflate, but I believe it will," Lakin said. "I hope it does deflate and balance rather than burst, and I believe this may well be the case as oil prices will come back more quickly than predicted – due in part to the incremental annual increase in global demand and the decline and lack of investment in conventional fields (which are still responsible for more than 90 percent of the world's oil supply), which is estimated to have been less than 50 percent of the investment needed to maintain such fields, (which are) declining at an average of 5-9 percent annually over the last three years, and the inability of even a rebalanced resource sector to fill the gap."

"And when it does, the money will switch back to conventional E&P players focused on high quality G&G who have a track record of finding oil and gas and generating long term values," he predicted.

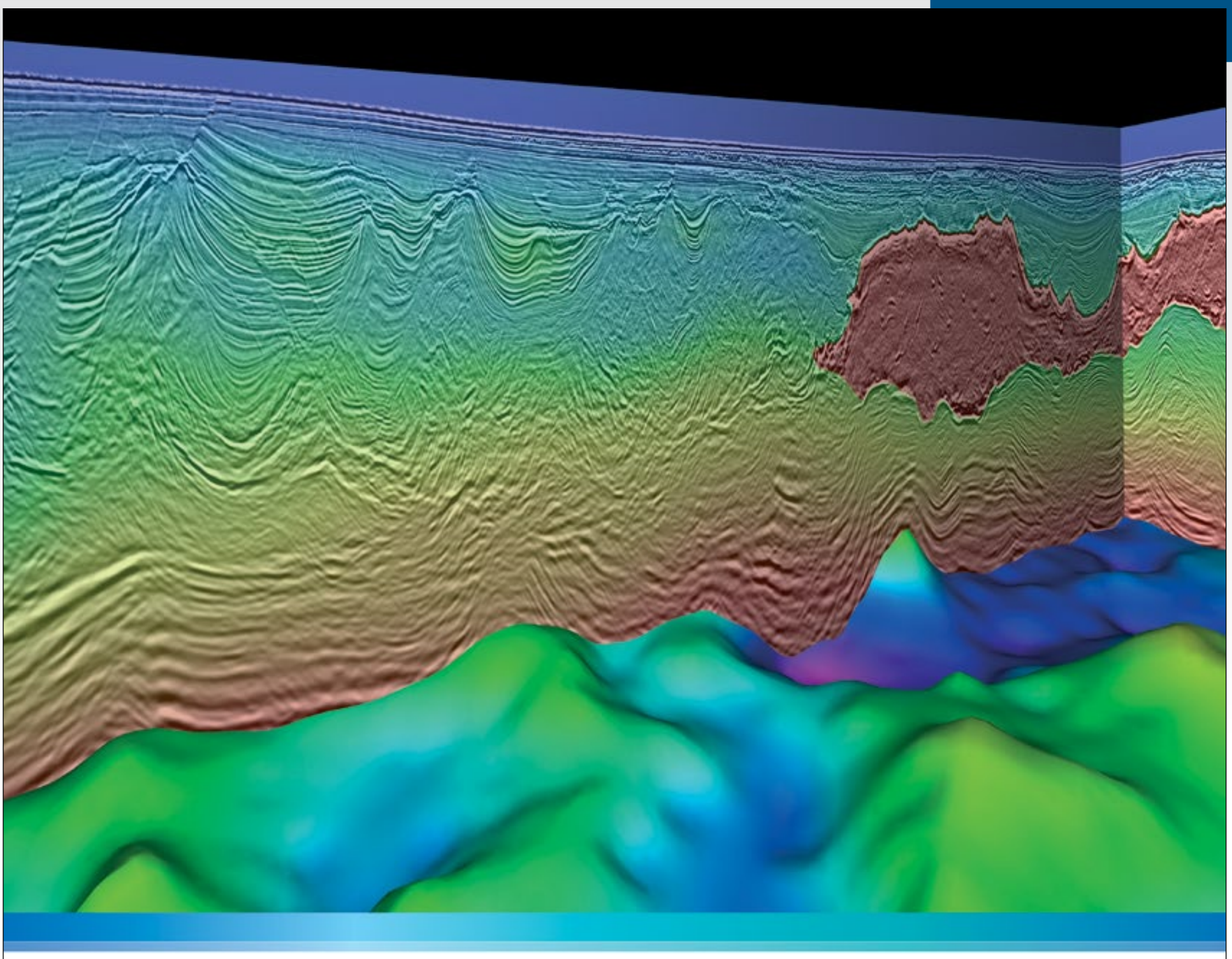
Overall, the winning approach likely will be "good sound geology for conventional and profitable tight conventional plays, which may still need stimulation with frac'ing as they have always done," combined with improved technologies to enhance E&P results and field life.

## Skills Gap

"That said, technology is probably only half the story as more mistakes and human error may end up being made with the looming G&G experience loss and knowledge-base decline as the older generation retires, and cannot not be replaced due to the generation of G&G people not employed in the last 1984–2003 crash, which has left a massive hole in the expertise treadmill," Lakin said.

"Perhaps the industry will realize soon that the writing has been on the wall as the G&G expertise age demographics have clearly shown for some time, where we will have no option to employ many of these older folks as mentors and advisers

See **Crew Change**, page 14



# Space Exploration is a Growing Field for Geologists

By BARRY FRIEDMAN, EXPLORER Correspondent

If you want to talk about the contribution of geosciences to the space program through the decades and those of geologists specifically, it's good to know Harrison "Jack" Schmitt.

He was the first geologist up there.

Schmitt's tenure at NASA was groundbreaking, for he was, in fact, the first trained geologist selected by NASA. Previously, the agency hired only test pilots. In hiring Schmitt, the agency and the Apollo program had someone who could explain to astronauts who got to the moon about the ground beneath their feet.

(Schmitt occupied the lunar module pilot seat on Apollo 17, the last Apollo mission. He was the second-to-last person to set foot on the moon's surface. Eugene Cernan was the last.)

## Mutual Benefit

The partnership between the geosciences and NASA in the early days of Apollo, Schmitt said, was fluid, indirect and beneficial to both.

"The main connection would have been indirect, as our work was not done purely out of government and academia," he said, and by this he meant that many of scientists who worked for Apollo also consulted for industry at various times.

It wasn't, however, just the personnel.

"Some of the instruments flown," he said, alluding to "passive and active seismometers and magnetometers," to name a few, had industry technology in their backgrounds.

"I personally had significant industry awareness due to my past education and experience and was deeply involved in training and operational development of experiments."

## Astrogeology's Many Facets

So what has happened since? What is happening now?

The work, as the cliché reminds us, goes on. And the distance between public and private enterprises is closing – by design.

"Over the last 12 months, there have been important developments in the commercial space industry, both for Mars in the long term and for the moon in the near-term," said Clive R. Neal, a professor in Department of Civil and Environmental Engineering and Earth Sciences at the University of Notre Dame.

"The Lunar Exploration Analysis Group (LEAG) has a commercial advisory board (CAB) that has grown dramatically since its inception in 2015. Through the CAB, we can see first hand the growth of the commercial lunar sector."

Neal said this work provided a permanent regulatory framework for public-private commercial lunar missions, something NASA, he said, should consider (spoiler alert: it is). For NASA, he maintains, such partnerships will result in shared risks and mitigated budgetary concerns. For the commercial sector, the potential is limitless.

"Obviously, interest in the moon by the commercial sector means they think they can make money," said Neal.

To that end, there was a "Back to the Moon" workshop in June that, according to Neal, was a game-changer.

"Also unveiled at this meeting and over the summer were the capabilities for companies such as Astrobotic and Moon Express to not only land payloads on the lunar surface but also architectures to return samples from the moon. Once these capabilities are proven, a lunar sample return campaign will become possible, which is important for both science and exploration (i.e., "in situ resource utilization," or ISRU). In addition to Astrobotic and Moon Express, the United Launch Alliance has announced its Cislunar 1000 Vision, whereby a refueling architecture is established in cislunar space and supplied using lunar resources. Blue Origin and SpaceX also announced rocket development that would enable large payloads to be delivered to the lunar surface to establish infrastructure for ISRU and develop a moon base."

The opportunities for growth, then, between geology and space exploration are not only planned for the future, they're here now.

"Our division at the Johnson Space Center employs a wide variety of geologists," said Cynthia Evans, the chief of the Astromaterials Research and Exploration Science (ARES) Division, adding that there are "many roles for geoscientists at NASA."

Specifically, ARES performs the physical science research at Johnson Space Center (JSC) and serves as the JSC focus for support to the HQ Science Mission Directorate, performing research in earth, planetary and space sciences, and has the curatorial responsibility for all NASA-held extraterrestrial samples. ARES scientists and engineers also provide support to the human and robotic spaceflight programs with expertise in orbital debris modeling, analysis of micrometeoroid/orbital debris risks to spacecraft, image analysis and earth observations.

Evans explained that the work is multifaceted and involves managing the astromaterials curation laboratories (including the samples from the Apollo missions, meteorites collected in Antarctica, cosmic dust collected from high altitude aircraft, comet samples, interstellar stream particles, asteroid samples and solar particles that were collected on various sample return missions). This aspect, she said, "preserves, protects and allocates those samples for researchers around the world."

In addition, ARES' scientists, including its many geologists, conduct fundamental research on those samples, including daily operations and research using instruments on robotic missions like the Curiosity rover on Mars and the Lunar Reconnaissance Orbiter.

And for that, obviously, you must have people, like Schmitt, who have expertise in these areas.

"We have scientists participating in future sample return missions from carbon-rich asteroids, with interests in exploring comets, icy worlds, polar regions of the moon, to name a few destinations," said Evans.

*Schmitt collects lunar rake samples at Station 1 during the first Apollo 17 extravehicular activity at the Taurus-Littrow landing site. This picture was taken by astronaut Eugene A. Cernan, Apollo 17 commander.*

*Cynthia Evans, chief of the NASA's Astromaterials Research and Exploration Science (ARES) Division, taking a break from collecting meteorite samples in Antarctica. Photos courtesy of NASA.*

## Manned Missions

The geologists at ARES are also working on and supporting experiments on human missions (the International Space Station), including Earth observations, and other remote sensing payloads mounted on the ISS platform.

"Some of our geologists," Evans clarified, "are funded to investigate tools and operations using analog environments on Earth to better prepare for future human missions to planetary surfaces. And, we also train the astronaut corps in basic Earth observations from the ISS, introduce them to geologic field methods, and provide an overview of NASA's planetary missions."

As for the scientists themselves, Evans said, "Most of our geologists have Ph.D.s in geology or planetary sciences, many are geochemists with extensive experience with analytical instruments and remote sensing, as well as field work. We have had many technical exchanges with the petroleum industry on technology developments (such as) analytics like using instruments like micro xCT, image processing algorithms,

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# Clouding the Issue of Global Warming

## *What's going on with climate models?*

By DAVID BROWN, EXPLORER Correspondent

*Clouds of different types have wildly different effects on temperature and climate, which scientists are only now beginning to understand.*

Maybe drawing a line in the sand isn't the best approach to climate change, especially when the sand is shifting.

A paper published in the journal "Nature Geoscience" in September theorized that the Earth might be warming a little less than climate models have predicted, by 0.3 degrees Celsius (0.54 degrees Fahrenheit).

That small number drew a lot of attention, because almost all climate scientists agree that it takes a substantial amount of emissions to warm the planet by even 0.1 degrees Celsius. If the lower estimate is correct, it would give the world more wiggle room to meet emission and warming targets.

Responses were predictable. Climate skeptics said, "All the climate models are wrong!"

"The Daily Telegraph" newspaper in Britain actually used that as a headline, "Climate models are 'wrong.'"

Climate alarmists considered the new estimate too revisionary, and couldn't imagine actually increasing the world's carbon budget.

Some climate scientists noted that the new level was still at the low end of a range predicted by a group of climate models, essentially saying, "This is within the possibility of how things might go – if things go that way."

And the general public was left thinking:

"What's going on with these climate models?"

So it's time to ask why there's such a variation in climate models, and what climate scientists are doing to improve their models.

### Butterfly Effect

It turns out that one of the most important factors climate scientists are now trying to understand are clouds.

In fact, how clouds work and what's going on in the deep ocean are probably the two biggest puzzles climate scientists are trying to solve.

NORRIS

> **"Every global climate model does clouds the wrong way. Some do it worse than others, but they do it wrong."**

"Every global climate model does clouds the wrong way. Some do it worse than others, but they do it wrong," said Joel Norris, professor of climate and atmospheric sciences at the Scripps Institution of Oceanography in La Jolla, Calif., part of the University of California, San Diego.

Clouds cool the planet because they reflect sunlight back into space. They also warm the planet because they trap heat. Different kinds of clouds have different effects. And it's hard to predict where clouds will generate in a long-range scenario.

Clouds give climate scientists the willies.

"One of the things I've been looking at is how clouds have been changing over years and decades," Norris said.

That's not a simple lab experiment, he explained. It requires monitoring equipment and other assets, like airplanes to fly into clouds. Clouds might have changed little, maybe 1 percent, but "that 1 percent actually matters a lot for how much the Earth warms," Norris observed.

Recent observations have shown more cloud coverage shifting toward the poles and cloud tops stretching higher into the atmosphere. Norris said we have better evidence for those changes, "and if they continue as we expect, they will also matter."

"One of the challenges (in climate science) is that things that matter happen on a small scale, and how do you represent that in a simplified way?" he said.

In current climate work, "clouds are a big part, but aerosols and how they interact with clouds are also getting a lot of study," Norris said.

"Another big part is trying to understand how the atmospheric circulation will change and how that will affect rainfall patterns where people live," he said, adding that there are also questions about ocean circulation, especially in the deep ocean.

"We know small things vary. And that matters," said Andrew Gettelman, senior scientist at the National Center for Atmospheric Research in Boulder, Colo. Gettelman wrote the book "Demystifying Climate Models" with co-author Richard Rood.

### Climate Model Shortcomings

"It's hard to know if our climate models are correct. We don't really know the current state of the atmosphere," he said. "We can't describe things happening in the atmosphere at the level of detail we need."

Climate models begin with the same approach as models used for short-term weather forecasting. In weather prediction, getting the large-scale motions of the atmosphere right is the critical step, Norris said. Climate prediction presents a more complex challenge on a time-scale of decades.

So why trust climate models at all?

"The advantage is, we know what the energy balance is. We have these large-scale constraints for climate modeling, which we don't have for weather modeling," Gettelman noted. "Those large-scale constraints help us because we can add up all the elements in the system."

"My ultimate philosophy of climate modeling is, you constrain every aspect of the model to be realistic. The foundation is the fundamental laws of physics. We don't violate any of them," he said.

Norris, who isn't a climate modeler himself, thinks there are limits to the usefulness of climate models.

"Climate models have been popular, but I don't know in the big scope of things how much we've learned from them," he explained.

"The way I look at them is, they're a useful tool," Norris said. "Climate models are better for analyzing processes, and not for getting a quantitatively precise answer."

### Predicting and Shaping the Future

It's time for some definitions and background:

A "climate model" is a set of equations designed to approximate the workings of the Earth's climate system in a simplified way. Still, climate models can be complex, sometimes requiring a supercomputer to process.

An "ensemble" is a selected group of climate models. No single climate model is likely to mirror the Earth's climate system exactly, so scientists use an ensemble to produce a range of possible outcomes.

A "forcing" is a factor that affects climate. Positive forcing makes the planet warmer; negative forcing makes it cooler.

The troposphere is the lowest region of the atmosphere, extending up about 10 kilometers from the Earth's surface.

See **Paris**, page 12

*Blue Origin recently successfully tested the BE-4 rocket engine, a component of its New Glenn vehicle.*

## Prospecting
from page 8

contamination control for organic species, understanding the microbiology and potential sources of contamination in our laboratories."

"Some of our staff members have experience in the oil industry. We are investing more in understanding carbon in the solar system, and have organic geochemists and geomicrobiologists on our staff," she added.

### Future Opportunities

For their parts, Neal and Evans are ready.

Neal said, "Prospecting is the next logical step in further developing the lunar economy, and if sufficient reserves are discovered, they will enable a sustainable human Mars exploration program through the involvement of the growing lunar commercial sector."

"The future looks good," echoed Evans, who added, "At the moment, we have about 200 people here and I'd say 150 of them are geologists, some having worked here for 40 years.

The agency hires an additional 5-10 per year. Additionally, as NASA will partner with private sector companies, which are interested in collaborating on future planetary missions, there will be ample and additional opportunities in the years to come.

"The demand is growing for geoscientists," said Evans.



## Paris
from page 10

The Paris Climate Accord was negotiated in 2015 by 195 nations plus the European Union. A goal of the accord is "holding the increase in the global average temperature to well below 2 degrees C above pre-industrial levels, and to pursue efforts to limit the temperature increase to 1.5 degrees C."

If you want to run a climate model for future decades, you have to make assumptions about processes and inputs. You'll need to make projections. How many volcanoes will erupt in the next 30 years, and how much ash will enter the atmosphere? How will cloud formations emerge, and where?

While it is possible the climate models themselves are badly flawed, it's more likely that the assumptions have been far enough off to cause a miscalculation of projected warming – not by degrees or even a single degree, but by a fraction of a degree.

And that's exactly what the authors said in the "Nature Geoscience" paper, published online as "Emission budgets and pathways consistent with limiting warming to 1.5 degrees C." The paper was written by Richard Millar of the Environmental Change Institute at the University of Oxford, with nine co-authors.

The new, 0.3 degree Celsius-lower estimate of warming seemed to take everyone by surprise. It probably shouldn't have. Dozens of papers have appeared in the scientific literature that address the climate models' overestimation of warming.

In June, the very same journal included a paper titled "Causes of differences in model and satellite tropospheric warming rates," by Benjamin Santer of the Lawrence Livermore National Laboratory and 15 co-authors, including climatologist Michael Mann.

"In the early 21st century, satellite-derived tropospheric warming trends were generally smaller than trends estimated from a large multi-model ensemble," the authors noted.

"We conclude that model overestimation of tropospheric warming in the early 21st century is partly due to systematic deficiencies in some of the post-2000 external forcings used in the model simulations," they wrote.

Climate scientists will be debating the latest findings for years. The bottom line is there's a belief out there right now that the planet has warmed a little less than scientists had expected.

And that's a good thing.

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experiences working in integrated teams: "experiential learning" with real data sets (like the AAPG Imperial Barrel Award program) and building up a knowledge of analog fields and exploration strategies (like those presented at AAPG Discovery Thinking and Playmaker Forums). AAPG is listening to what is needed and we are exploring ways to provide maximum relevancy.

Our Future Workforce Trends Committee is expected to be a big help in that mission.

Many people believe that creativity can be trained. I remember the first prospect map I made when I worked for Shell as a new hire many years ago. I learned the process from a mentor. I combined stratigraphic tests and 2-D seismic. My hand-drawn contours defined a spot to drill. What a thrill to be the well site geologist as we flared gas – a bright light in early morning darkness. I can still feel the warmth of a roaring flare stack as a new field came to life that very cold winter day.

AAPG has a high volume of energy relevant content and events in store for year to come:

- We are allotting more content pages in the AAPG Bulletin, which will focus on super basins.
- GEO 2018 will be March 5-8 Bahrain.
- The Global Super Basin Leadership Conference in Houston is gaining momentum, and there will be more information in upcoming issues. Note the new date of March 27-29.
- The AAPG Annual Convention and Exhibition (ACE) will be May 20-23 in Salt Lake City, Utah. Its theme will be "ACE 101: Bridging Fundamentals and Innovation." Thanks to Michael Vandenberg and his team for what promises to be a great meeting. I am so passionate about this program that I am chairing three panels (with great co-chairs): Discovery Thinking (the 20th panel session!), an innovation panel and a forum on super basins.
- The Unconventional Resources and Technology Conference (URTEC) will be July 23-25 in Houston.
- The International Conference and Exhibition (ICE) will be Nov 4-7 in Cape Town, South Africa. It will be a strategic conference to build on an exciting series of exploration plays and super basins.
- Other conferences include APPEX Global London in March (see page 4 for more information), GTW's and Section and Region meetings around the globe.

### Three Questions for Innovators

Can we imagine it, can we image it, and can we get to it? Value innovation requires relentless reduction of costs with huge improvements in quality. Super basins, like the prototypical Permian Basin, are innovation proving grounds. Richly endowed petroleum systems need access, favorable regulations and infrastructure to thrive. Our industry is not standing still. Though we have learned much, we are still in our early days of resource plays and the decades ahead are quite promising. Next generation completion technologies are continuing to revitalize plays like the Haynesville and others. Continued value innovation is working its way through the exploration playlist.

Innovation is needed during price retrenchments. Some of the most impactful innovations in drilling, completion, logging, geophysical technologies and concept evolution happen when product prices are low or at a long-term sustainable level. This is a great time for innovation in both our industry and at AAPG.

Charles A. Sternbach



## Crew Change
from page 6

with their irreplaceable experience, or face the E&P consequences," he added.

On the one hand, he sees "plenty of experienced people appear to be looking for work now, but too few when the E&P sector really turns."

This loss of experience, knowledge and expertise in the oil and gas industry – a result of the Great Crew Change and recent layoffs and retirements – troubles Lakin.

The result is a significant gap between the experienced professional workforce over 54 rapidly leaving and the contingent of new hires younger than 35 slowly coming on board, and Lakin warned that the industry has to "mind the gap."

"To put this in context, an experienced U.S. geologist mentioned at NAPE earlier in 2017 that he'd recently employed a young geologist who had never seen a conventional log and would not quite believe how good the reservoir quality was," Lakin said.

### International Deal-Making

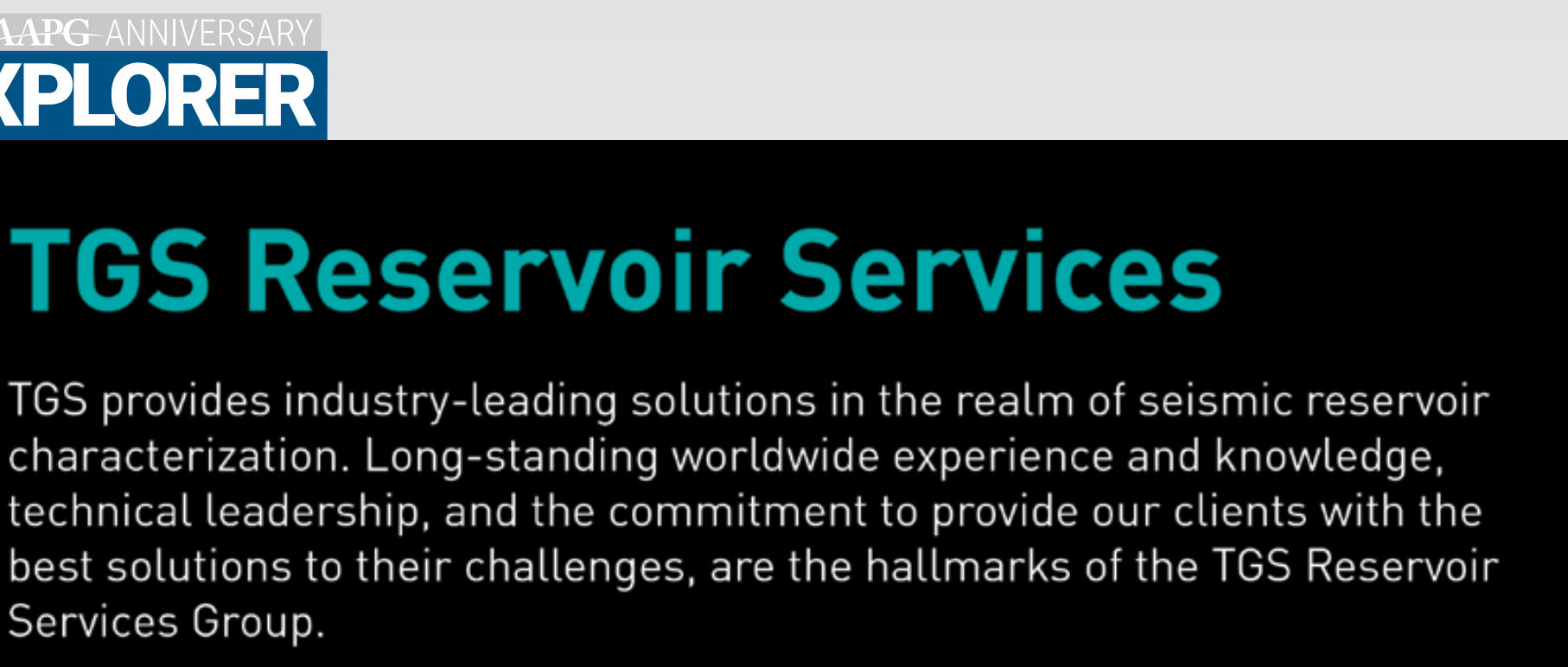
The first-time APPEX expo-goers might find Islington a surprisingly comfortable place to conduct international E&P deal-making with many of the worlds key A&D people all under one roof. Lakin described it as removed from the overcrowding, rush and distractions of many other less specific industry shows that can be found in other parts of the world.

"The venue is the best in London for such an event," he said. "And we've been there for 14 or more years, so people are familiar with the space and comfortable with APPEX's reputation for international deal-making."

# TGS Reservoir Services

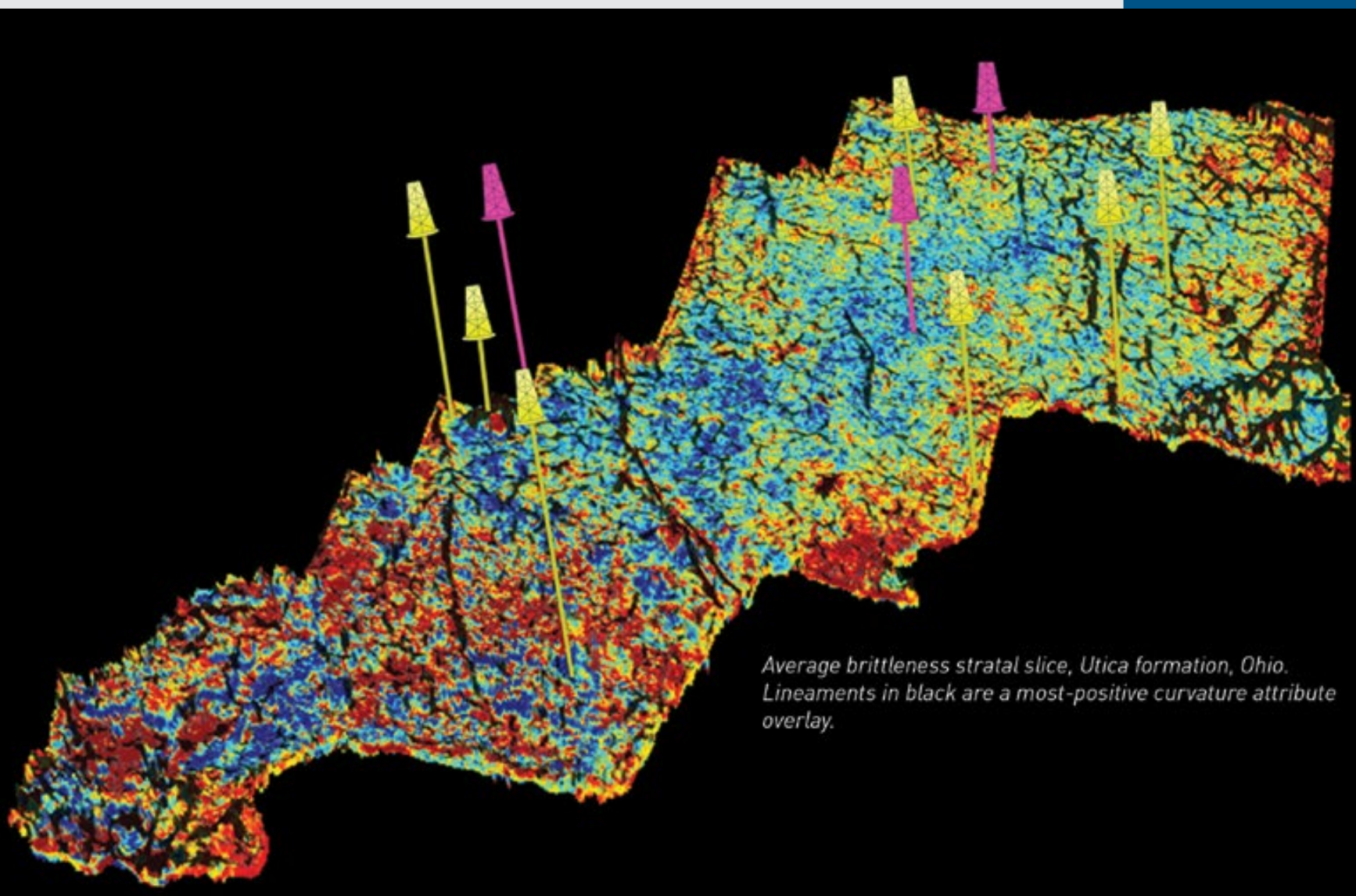
TGS provides industry-leading solutions in the realm of seismic reservoir characterization. Long-standing worldwide experience and knowledge, technical leadership, and the commitment to provide our clients with the best solutions to their challenges, are the hallmarks of the TGS Reservoir Services Group.

Distributed resource plays, whether shale, tight oil, or other unconventional variants, continue to prove challenging in terms of predictability. The goals for seismic characterization of resource plays include the determination of lateral variations of elastic and petrophysical properties within rock units. The understanding of how these relate to well performance leads to quantitative seismic reservoir characterization and the application of these data to support predictive analysis.



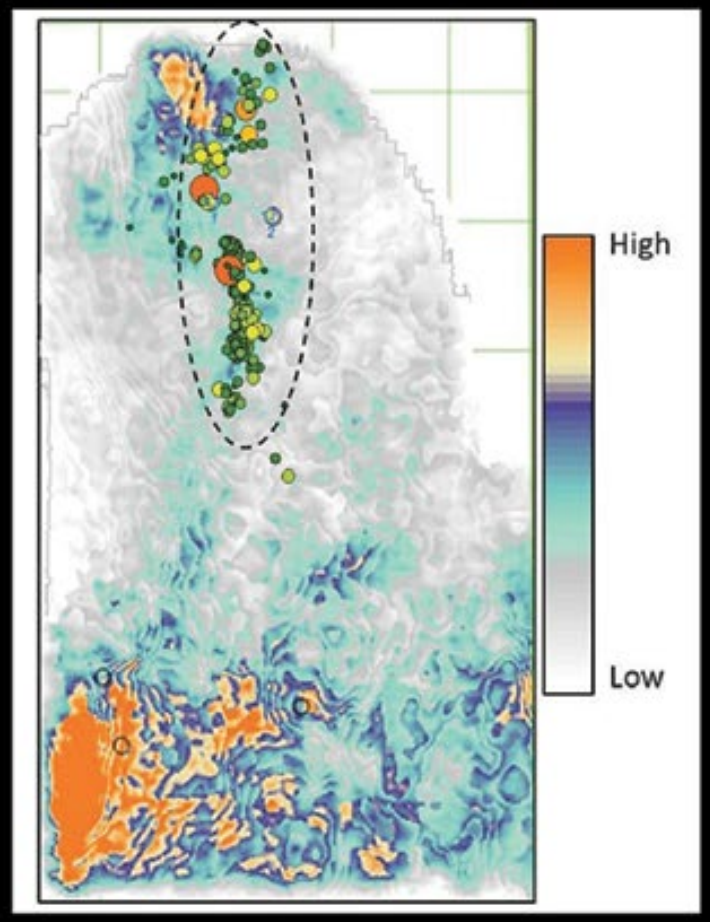

*Arbitrary line through an acoustic impedance volume passing through five wells. The acoustic impedance volume as well as a Gamma Ray volume generated using neural networks were used together to generate facies a volume for the Vaca Muerta shale interval, Argentina (Data courtesy: Pan American Energy)*

See the energy at **TGS.com**



*Average brittleness stratal slice, Utica formation, Ohio. Lineaments in black are a most-positive curvature attribute overlay.*

At TGS we seek more meaningful approaches to shale characterization. For example, where appropriate, we describe shale zones in terms of 'fracture toughness' , which is measure of resistance to fracture growth. This offers better results in various shale formations across North America, especially where brittleness and stress strain do not always correspond to a typical high Young's modulus and low Poisson's ratio relationship.




*Horizon slice from a volume of inverse fracture toughness from the Duvernay formation in the Fox Creek area of central Alberta, Canada. The relative values of inverse fracture toughness correlate well with the induced seismicity shown by relative magnitude bubble data overlaid on the display. Induced seismicity data is courtesy of Repsol Oil and Gas, Canada.*

TGS

*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.*

# 'Sowing the Oil': A Little-Known Venezuelan Oil-Industry Initiative

By DAVID HOLMES

Ever since the 1940s, the stated objective of the Venezuelan government was to use oil revenues to diversify the economy and reduce the grinding poverty of a large segment of the population. But, successive governments made relatively little progress. In fact, the opposite occurred: explosive population growth, decline of the agricultural sector and increasing availability of public sector jobs in the major cities triggered a massive urban migration and a corresponding growth of urban slums. This set the stage for the so-called "Bolivarian Revolution" in the late 1990s, the principal achievement of which was to reduce income disparities by making everyone equally poor.

In contrast, a rather unique socio-economic development emerged within the oil industry itself during the 1980s, based on notions of "appropriate" technology, energy efficiency and donor/recipient collaboration. Although it was carried out on a relatively modest scale, it won a number of national prizes for technological development and conservation. Ironically, this experiment evolved, not primarily in response to the broader mandate to "sow the oil," but rather in answer to the practical needs of the now government-owned industry, to peacefully and responsibly integrate with its new immediate neighbors in the Orinoco Heavy Oil Belt.

As far back as the 1950s, the enormous deposits of heavy oil beneath the southern plains of Venezuela were detected and partially explored, but not exploited. However, rapid global oil price increases in the 1970s and new techniques for extracting and processing heavy oil, coupled with Venezuela's declining conventional reserves, gave the Oil Belt a new lease on life.

This created a dilemma.

In the traditional areas around Lake Maracaibo, oil company employees lived in privileged camps with independent housing, schools, health care and recreational facilities. Early in their history, these camps became surrounded by ugly shanty towns whose leaders incessantly nagged the largely foreign companies with seemingly insatiable demands. However, following nationalization in 1975, it was forbidden by the Venezuelan government to construct any new oil camps and the existing camps were instructed – like it or not – to integrate with surrounding communities.


*Maraven's local headquarters was directly south of the small Venezuelan town of Pariaguan, which benefited from the oil company's generous social outreach.*

**David Holmes** is a retired, Harvard-trained economist and engineer. His doctoral dissertation was on "Rural Credit in the Andes Region of Venezuela." For 40 years he was resident in the country where he worked for the Harvard Institute for International Development and for PDVSA affiliate Maraven. He currently divides his time between Florida and West Virginia.

Still, until the Oil Belt opened up, this new policy was honored more in the breach than in the observance

## The New Social Strategy

In the face of the new integration mandate, the ex-Shell affiliate, Maraven, decided to take the social and economic development of its neighbors seriously. Accordingly I, an employee of Maraven, was assigned the task of heading up a new Department of Integral Development.

While a brand new company headquarters was under construction in the small (30,000 population) town of Pariaguan, on the northern border of the block, without the usual barbed wire fences or restricted entry, we undertook an extensive diagnosis of the town's basic public services such as potable water, waste-water treatment, health care facilities, housing and local government. Based on this, the task force planned and, over the course of the ensuing years, undertook many collaborative works to upgrade basic public services in partnership with the responsible government agencies at the local, state and national levels.

Some critics in the company feared that this new aggressive social outreach might elicit resentment from the responsible government agencies and the political parties, which might see this as an unwarranted intrusion into their traditional areas of responsibility. Others feared the opposite – that bureaucrats and politicians would simply try to foist most of the burden of social programs on the company.

In practice, however, the reaction was quite the contrary. Government leaders at all levels welcomed a new, objective evaluation of community needs, untainted by narrow partisan bias. Furthermore, the task force offered logistical and technical support, which greatly facilitated government activities in the zone, often enabling responsible officials the opportunity to carry out their duties, in some cases for the first time, in this remote area.

Maraven's reputation of proposing solutions, not just identifying problems, assured that government doors were always open. In this way, a mutually beneficial alliance was forged which resulted in many innovative projects and substantial improvements in the efficiency of public investments with minimal cash outlays by the oil sector. One of the outstanding examples was the design and construction of an oxidation pond system, using only solar energy and gravity flow, for the processing of Pariaguan's sewage. Heretofore, this had been dumped, raw, into the headwaters of one of the principal rivers supplying drinking water to a large, coastal city. This project was awarded the "Enrique Tejera" National Conservation Prize at the Fifth National Conservation Congress in 1989.

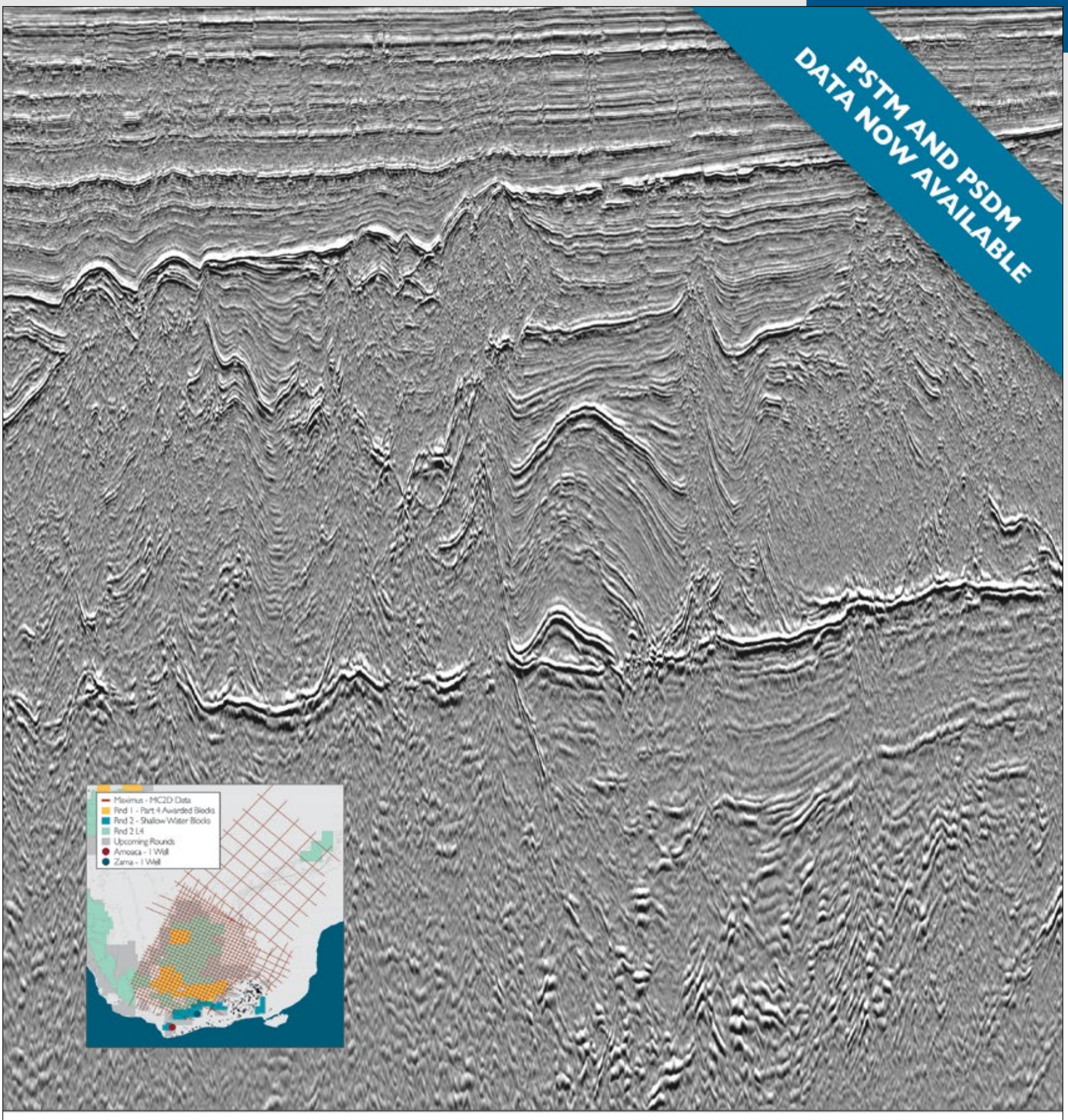
Maraven faced a difficult dilemma in securing adequate schooling for its employees' children. The initial intent was to send them to the public schools but we soon learned that the local school system was broken, almost beyond repair, reflecting the broader, national crisis in public education. So Maraven ended up constructing a new private school, primarily for the children of the oil workers, but also open to deserving local students. Attention was also focused on rural schools resulting in the creation of a number of "energy independent" units featuring passive solar cooling, lighting and fans powered by solar panels, with rainwater collection systems and VIP (ventilated, improved pit latrines which eliminated foul odors without the use of water, using only solar and wind power). A comfortable apartment for the rural teacher was also included. This model school later received a national prize for technology development awarded by the National Scientific and Technological Research Council in 1987.

In order to assess the health status and further needs of the youth in the community, we conducted a survey and physical examination of school-aged children. Overall, nutritional status turned out to be relatively normal but we were surprised to find that not even one child had ever seen a dentist, although a high

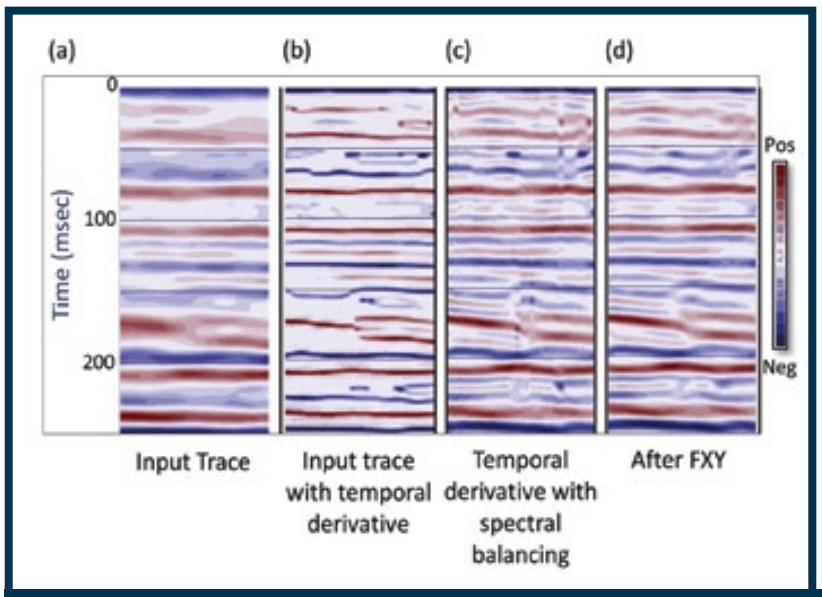
See **Dental**, page 23

*The author working on the design of the solar powered dental drill that was later put to use among the tribal people in the mountains between Venezuela and Colombia.*

*Community members helping to construct the VIP latrine under the direction of Maraven technician.*



*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.*



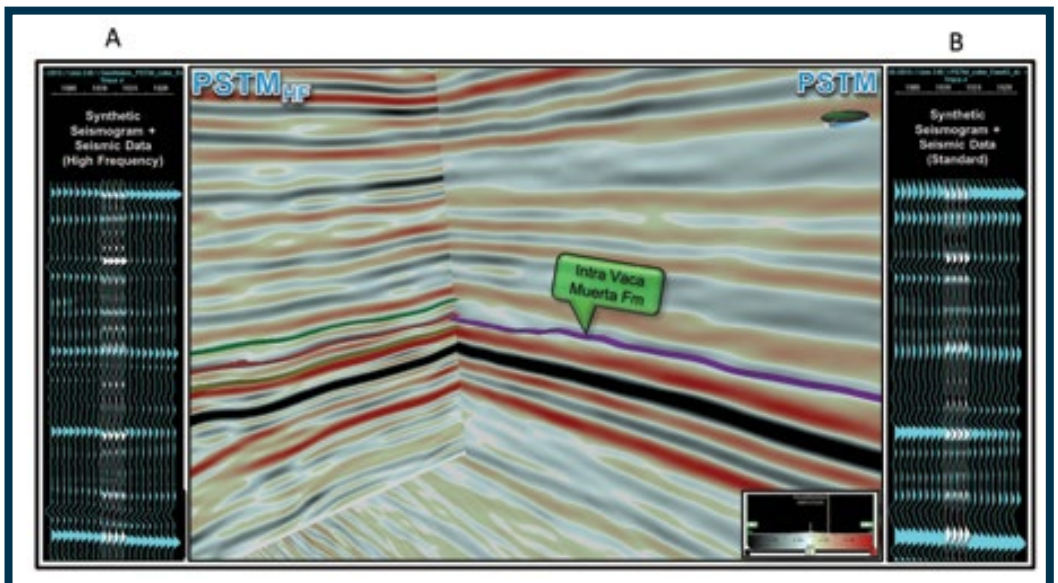




*Figure 1: Workflow for seismic frequency restoration process, which exhibits a result with overall higher resolution. Figure 2: 3-D perspective view showing a crossline to the right from the PSTM 3-D seismic data volume. The data is from the Neuquén Basin, Patagonia, Argentina. An inline from the frequency-restored 3-D seismic data volume is shown to the left. Notice the enhanced frequency content on this inline. Synthetic seismograms generated from the input and frequency-restored data are shown on the sides respectively. The high correlation seen on the frequency-restored data lends confidence in the process used therein.*

# Attributes at Your Fingertips

By LUIS VERNENGO, EDUARDO TRINCHERO, MAXIMILIANO GARCÍA TORREJÓN and IGNACIO ROVIRA of Pan American Energy LLC

The development of interpretation software is a direct consequence of ongoing advancements in geoscientific technology, which helps in their application to seismic data. It might be assumed that this proliferation of knowable attributes would be helpful to interpretation, but in several cases this is not true, as many of the seismic attributes are redundant, and seismic interpreters are often confused by the incredible scope of attributes they can use in their work projects and the different options that are available therein.

One of the first questions a seismic interpreter must ask is how to recognize and characterize the reservoir. Understanding the geology and the depositional history of the area is a good start. Identification of the zones of interest is next, when well log data are integrated with the seismic data. Once one or more target zones are identified and the objectives for their characterization outlined, then the interpreter turns to seismic attribute computation to better visualize the data and enhance their description, both in the temporal and spatial directions.

Such objectives could vary from the understanding of the geological relationship of the target reservoir with the architectural subsurface elements of defining the reservoir in terms of fluid/ lithology distribution, or a physical property such as porosity, or to describe the geometrical or discontinuity patterns the reservoir is set in. Seismic attributes are selected accordingly and included in the workflow adopted for their generation.

This is a key step in understanding the seismic response corresponding to subsurface geological features; knowledge about the seismic attributes and confidence in their application are some factors that can help in such situations.

Often it is advantageous to keep the attribute applications simple, with just the "right" number of attributes employed in a project and keeping the end goal in mind.

## Enhancing Vertical Seismic Resolution

In order to understand the stratigraphic patterns or their behavior from seismic data, it is imperative that the amplitude and frequency are preserved while the data go through the different processing steps. Thus, the seismic data processing must be carefully supervised by the interpreters and calibrated with geological information. Any variation in the shape of the basic wavelet in the seismic data that is not related to the subsurface needs to be eliminated. Multiples and random noise will undermine the integrity of the results. All these steps are important and need to be carried out before any attribute computation is attempted on seismic data, or even before their frequency enhancement is attempted. It is also imperative to consider the assumptions on which the individual processes are based, at least for qualitative interpretation of attributes. For a more quantitative seismic interpretation, well log modeling and seismic correlation is required.

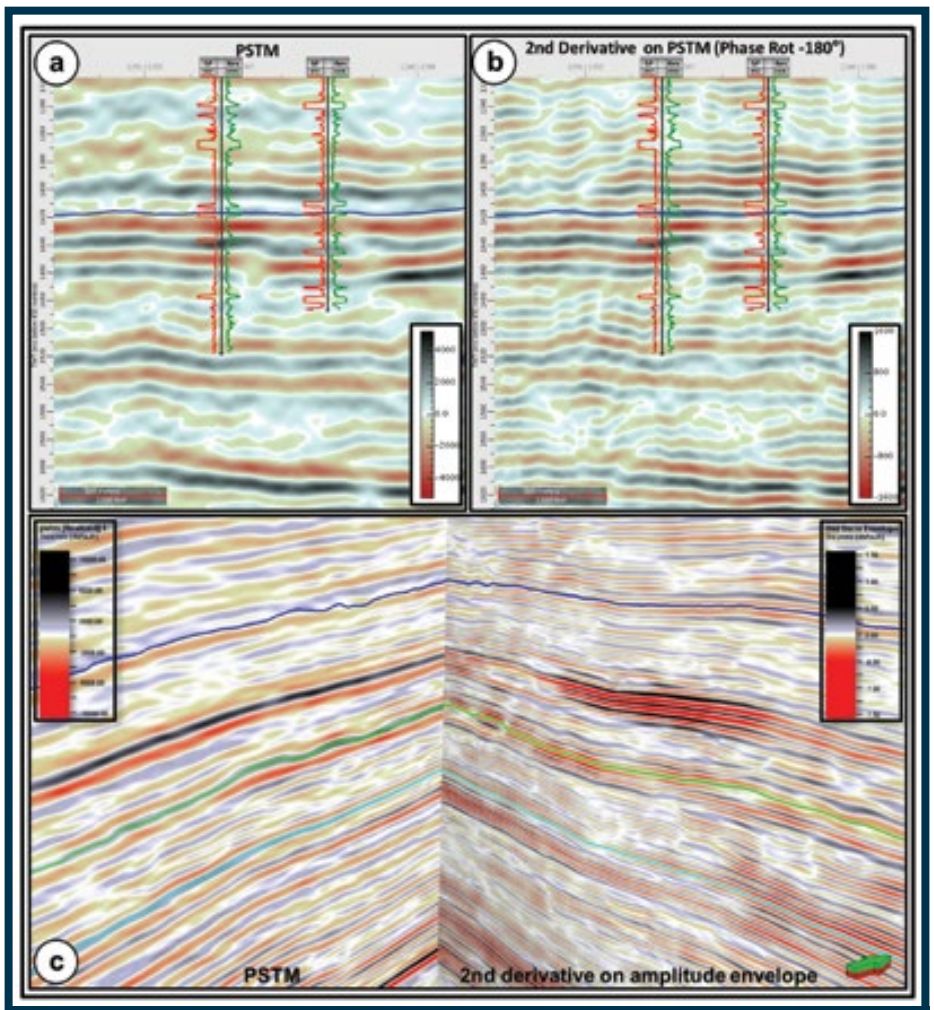



*Figure 3: (a) Segment of a seismic section from 3-D seismic data volume from the north flank of Golfo San Jose Basin in Patagonia, Argentina. (b) The equivalent section as in (a) but from the second-derivative attribute derived from the 3-D seismic volume. (c) 3-D perspective view comprising the PSTM seismic inline to the left, and a crossline from the second derivative of envelope attribute to the right. The increased frequency content seen on the right could result in somewhat lower signal-to-noise ratio, but the data helps in facilitating horizon picking through the volume. The greater reflection detail seen on the frequency enhanced data helps with better understanding of the geological context.*

For frequency enhancement of seismic data, a simple and a somewhat newer approach could be followed. The first step in such an approach is to subsample the seismic data: if the input seismic data has a two-millisecond sample interval, it is subsampled to 0.5 milliseconds using the Nyquist frequency as a limit. For the next step, the temporal derivative of seismic data is computed and each change of sign of the temporal derivative in the seismic trace is replaced by a pulse of equal magnitude and sign, indicating the point of change. This generates a new seismic trace for each input seismic trace that is formed from dispersed random pulses and has a higher bandwidth. This step is followed by a variable spectral balance in time and a bandpass filter in the range of expected frequencies. For the latter step, the frequency band is usually chosen within the original seismic sweep that is injected into the ground by the vibrators or the observed frequency range of the raw explosive-acquired seismic data. Finally, a random multichannel noise filter (FXY) is applied to the seismic data, taking care to avoid any artifacts. Figure 1A shows the results of the above-mentioned workflow applied to the input seismic data. Such frequency-restored results, exhibiting better vertical and lateral definition, help the interpreter to bring in more precision in the interpretation.

In figure 2 we illustrate the application of this frequency enhancement process for prestack time migrated seismic data (PSTM) from Neuquén Basin of Patagonia, Argentina. The figure shows a vertical seismic section to the right from PSTM seismic data, and to the left is the same data after restoration of frequencies with the proposed method. Notice the

Continued on next page

Continued from previous page

difference in the frequency content and resolution of the two displays. The target zone is around the picked horizon within the Vaca Muerta formation as indicated. The synthetic seismograms are generated with the before and after frequency restoration process, and using wavelet extracted from the respective seismic datasets using a statistical process, are shown to the right (B) and left (A) respectively. Notice the higher level of reflection detail after frequency restoration as compared with the input. We contend that the proposed method is important for defining the sweet spots in unconventional reservoirs and for generation of geomechanical attributes subsequently.

Besides the aforementioned method, another commercially available and commonly used method is called "spectral bluing." In this method, the seismic data and well log reflectivity are compared and a digital matching filter is extracted and applied to the seismic data. This method resurrects the attenuated frequencies in the subsurface.

## Second-Derivative Method for Accurate Structural Interpretation

Often the bandwidth of the seismic data being interpreted does not exhibit enough continuity or resolution for a satisfactory interpretation. In such cases, the second derivative computation of the input seismic data can help. It may be mentioned here that when the first derivative is generated, its phase gets rotated by negative 90 degrees. When the second derivative is generated, the phase of the seismic data gets rotated by negative180 degrees. Visually, this means that the polarity of the traces is inverted, or that the peaks become troughs, and vice-versa. In terms of interpretation, we notice enhanced reflection continuity in the seismic data, which is helpful, particularly in areas with disrupted or poor reflections, or for data with diminished lateral variations, where horizon picking is difficult.

We illustrate this aspect in figure 3, which shows a segment of a seismic section (figure 3a) from a 3-D seismic volume in the north flank of Golfo San Jorge Basin, Patagonia, Argentina. The equivalent section with the second derivative run on it is shown in figure 3b. Notice the overall enhanced continuity as well as the individual reflections around the interpreted reservoir (above the picked blue horizon), which appears as tuned in the PSTM section in figure 3a.

Sometimes, instead of running the second derivative on the PSTM seismic data, if it is run on the amplitude envelope attribute, the resulting attribute can minimize thin-bed tuning and aid the interpretation of major depositional strata or lateral lithologic variations. In figure 3c we show a 3-D perspective view correlation for a PSTM sections to the left, and the second derivative attribute section to the right. The picking of the horizon is facilitated on the section to the right. A considerable enhancement in the frequency content and enhanced signal-to-noise ratio are noticed, which are beneficial for interpretation of greater detail as well as more insight into the geological context of the zone of interest.

See **Co-visualization**, page 22

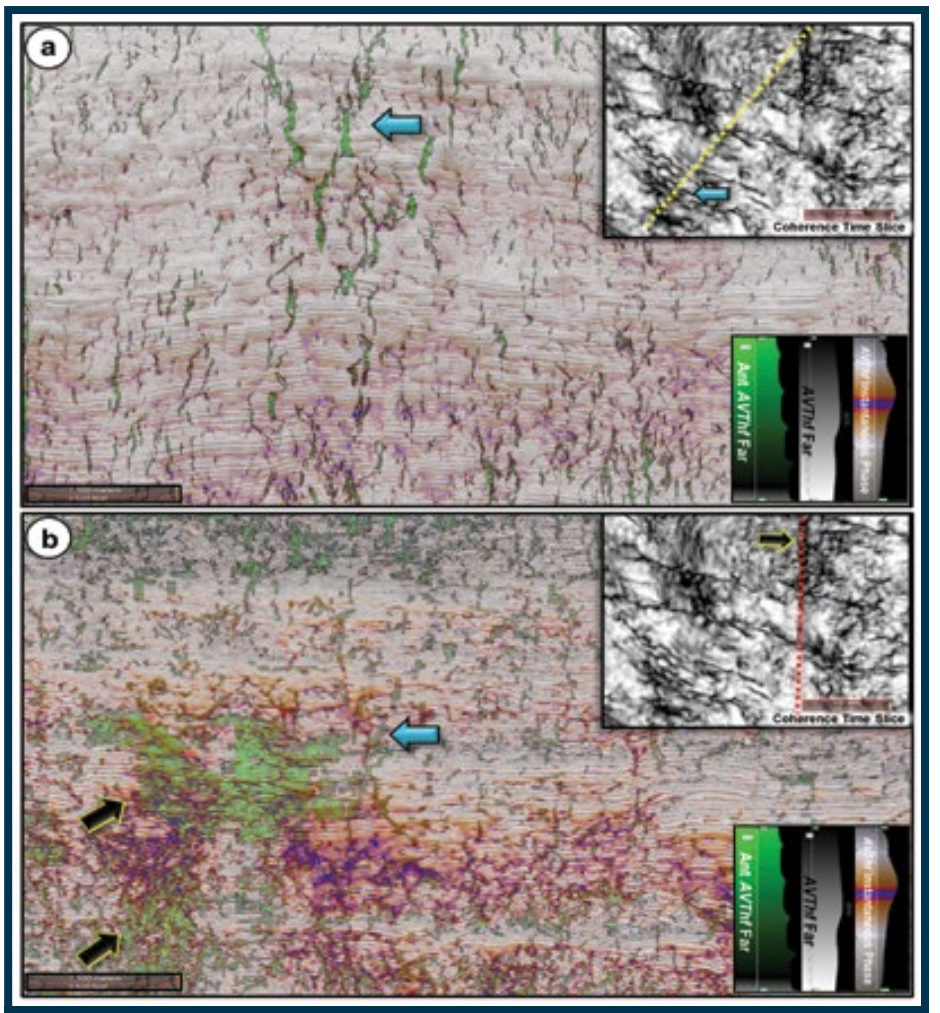
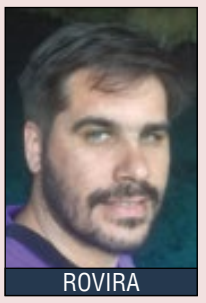



*Figure 4: Co-visualization of AVTHF far angle stack, instantaneous phase of $AVT_{HF}$ far and ant tracking on $AVT_{HF}$ far, from 3-D seismic data of Golfo San Jorge Basin, Patagonia, Argentina. Such co-visualization is useful for more accurate interpretation, as well as for understanding the subsurface model. In figure 3a, the fault system is seen clearly (marked with light blue arrows), as well as the effect of pseudo-weathering relief. Coherence time slices in the inset indicate the position of sections. Figure 3b shows the visual impact of the intrusive body filling the feeder zone and going up to the final emplacement (light green colored zone, pointed with black arrows). The structural events of different order are also seen.*


VERNENGO


TRINCHERO


TORREJÓN


ROVIRA

**Luis Vernengo** is the head of geophysics at Pan American Energy LLC, an independent oil company of Argentina. He worked for this company 20 of the 29 years of his career in the industry. He has a degree in geophysics from the University of La Plata (Argentina) in Facultad de Ciencias Astronómicas y Geofísicas. Vernengo has experience mainly in development geophysics: seismic interpretation, attributes and seismic inversion. He has worked in different basins around the world, especially in Latin America, in various geological structural and stratigraphic scenarios.

**Eduardo Trinchero** is a staff senior geophysicist at Pan American Energy LLC. He received a specialization degree in geophysics at the Universidad de Buenos Aires and a specialization degree in seismic interpretation at the Universidad Nacional de Cuyo. Trinchero has more than 30 years of experience in different aspects of seismic exploration and exploitation issues. He has a strong background in development geophysics, reservoir seismic interpretation, attributes, seismic stratigraphic interpretation, seismic acquisition and processing.

**Maximiliano García Torrejón** is a staff semi-senior geophysicist at Pan American Energy LLC. He has a degree in geophysics at the Universidad Nacional de San Juan, Argentina. García has nine years of experience in development geophysics, reservoir seismic interpretation, attributes, stratigraphic and structural interpretation and seismic inversion.

**Ignacio Rovira** is a staff geophysicist at Pan American Energy LLC. He received a degree in geology with an orientation in geophysics at the Universidad de Buenos Aires (Argentina). His background includes both onshore and offshore seismic interpretation as well as other geophysical methods. As a reservoir seismic interpreter he achieved strong skills in structural and stratigraphic interpretation and diverse seismic attributes application for both gas and oil field development.



## Co-visualization
from page 21

### Multiple Attribute Co-Visualization Aids Subsurface Interpretation

In subsurface areas that exhibit complex faulting, it is useful to blend seismic amplitudes with geometric attributes for more accurate interpretation. In the April 2017 issue of the Explorer, the authors described how the AVT (amplitude volume technique), and its higher frequency variants (AVTHF) help in differentiating geological contents in terms of definition of elements in a complex reservoir system.

In figure 4a we show a multiple attribute co-visualization of AVTHF ant tracking, the instantaneous phase of AVTHF, and AVTHF from seismic data (Note: all of AVTHF were calculated on far angle stack volume). The display exhibits the fault system very clearly as well as the effect of pseudo-weathering relief (light blue arrows). In figure 4b, the AVTHF on far angle stack as well as the instantaneous phase on the same data are shown covisualized. Notice the visual impact of the intrusive body (black arrows) shown in green color, fitting the feeder zone, and going up to the final emplacement.

In conclusion, we present some easy-to-implement seismic frequency restoration methods and attributes that can be adopted in the interpretation workflow so as to resolve geometry of stratigraphic patterns, rock properties and other characteristics of reservoirs. It is strongly advised that proper quality checks be put in place for each process described. For example, in the frequency restoration process described, a synthetic seismogram should be generated and correlated with the frequency restored seismic data. Such an exercise can be repeated in other wells so as to gain confidence in the interpretation of the frequency restored data or attributes generated thereon.

The processes or attributes described in this article will be helpful for an interpreter and enable the task to be accomplished in less time. The saved time can be devoted to reinforcing the play concept and/or refining the interpretation.

Acknowledgements: We would like to thank Pan American Energy LLC for permission to show the examples in this presentation, to Satinder Chopra of Arcis Seismic Solutions, TGS, Calgary, for the review of several parts of this paper and to Marcelo Roizman, GeoNodos, Argentina, for his technical contribution.

# Dental

from page 18

incidence of dental caries was nearly universal. The closest the children ever got was a visit to the local "tooth-puller." This spurred us to create one of our most successful programs involving an alliance with the dental school of the Venezuelan Central University in Caracas to provide final-year dental students the opportunity to staff rural dental clinics and receive academic credit. These we built using passive, solar-cooling architecture, and the same basic services package we supplied to rural schools. Thus, for the first time, the population of the zone had access to this vital service, and the young, largely female dental students had the opportunity to complete their rural training in a comfortable, secure and well-maintained setting.

This program received the "Research Initiatives" prize from the Venezuelan National Dental Association in 1993. As a follow-up to this project, we designed and built a complete dental clinic, including a high-speed, pneumatic dental drill, lighting and dental suction equipment, powered exclusively by solar panels, which could be mounted on the backs of two mules for use in remote areas that were inaccessible by road.

*The author in front of the fully portable dental clinic set up in conjuction with the dental school of the Venezuelan Central University.*

*Model rural solar-powered school at El Manguito showing the slanted roof for rainwater collection, the gutter and the tanks.*

### Other Rural Development Projects

An even more ambitious effort to strengthen and diversify the local economy and improve basic services was undertaken in the some 3,600 square mile exploration block, which consisted of a large tract of semi-arid and largely undeveloped plains between a major east-west highway on the north and the Orinoco River on the south.

The seat of local government was in the town of Mapire, on the banks of the Orinoco River. Although its economy depended almost entirely on fishing and cotton-growing on the alluvial islands of the river, the town had no port facilities. Accordingly, Maraven designed and constructed a concrete ramp providing a year-round road link to the river, which enabled cargos from the launches and barges to be unloaded directly onto trucks rather than carried by hand up the steep bank.

Mapire was also home to one of the last surviving of a series of farm schools built and run by the Ministry of Education. But, the school was run down, the livestock was nearly all gone and the farm machinery was mostly broken. Thus, the technical side of the curriculum was almost entirely defunct.

To rescue this important initiative, we provided a full-time resident manager for the farm under whose supervision the cattle nutrition and breeding programs were reinstated and a fish-culture project was added to supplement the fish supply during the annual off-season. The poultry program was also renewed and fresh milk, eggs and poultry were marketed locally on a commercial scale for the first time.

To assist the cotton growers of the zone, we partnered with the National Cotton Growers Association and the farmers themselves to provide technical and marketing assistance, which ended up producing some of the finest cotton in the world, largely for export.

The other mainstay of the local economy was extensive cattle ranching, using the most rudimentary technology of the "Turn 'em loose on the vast plains, and round up the survivors"-variety.

With relatively little effort, the productivity of the typical cattle ranch was substantially improved simply by greater attention to animal sanitation and pasture improvement.

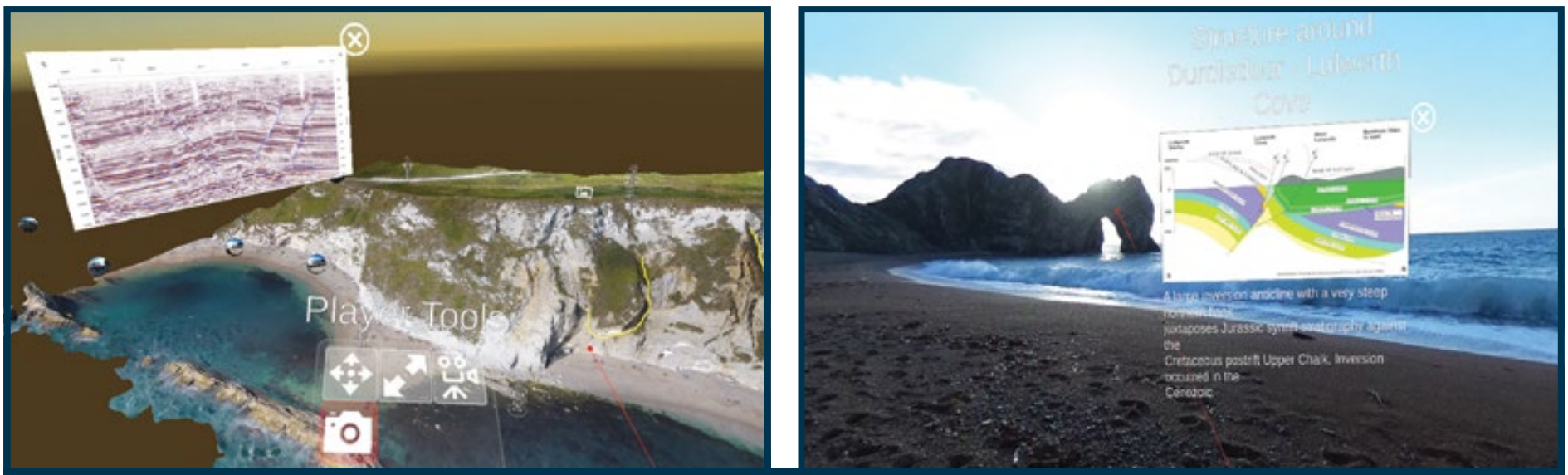
### As You Do Not Sow, Nor Shall You Reap

The discovery of commercially exploitable oil in Venezuela in the 1920s enabled the country to transform itself from a society based largely on

See **Transformation**, page 24

# Virtual Reality Brings the Mountain to the Geologist

By KRISTI EATON, EXPLORER Correspondent




*Durdle Door, a natural limestone arch on the Jurassic Coast near Lulworth in Dorset, England, served as the test example for Imaged Reality's VR field trip concept. Images courtesy of Imaged Reality.*

Claudia Ruiz-Graham moves the computer mouse over an outcrop model – an image she likely never would have gotten if it hadn't been for a drone snapping photos.

It's part of a video about Ruiz-Graham's startup company, Imaged Reality, which uses virtual reality – a computer-replicated environment – to map and examine sites.

And now, Ruiz-Graham is using it to help find oil.

Using the 3D Gaia application that Ruiz-Graham designed and a developer created (which launched at the AAPG International Conference and Exhibition in London last month), users can fly virtually anywhere on the Earth.


RUIZ-GRAHAM

"The app virtualized digital outcrop models," she said. "It also has tools that allow the user to interpret the digital outcrops directly in virtual reality. As the outcrop is virtualized, you can experience the outcrop at real scale, you can walk along it or you can fly over it."

Because the replicated environment is at real scale, it creates a fully immersive experience, she said.

"The app also integrates Google Earth, so you can virtually fly anywhere in the planet. It also integrates subsurface data, such as geological maps and seismic and well-log images," she said.

The digital outcrop models are generated from images using drones, she said.

For example, at Durdle Door, a limestone arch on the Jurassic Coast near Lulworth in Dorset, England, a user can circle around the cliff, viewing it in 3-D.

## Test Flight

Ruiz-Graham came up with the idea following the downturn in the industry. She noticed lots of layoffs and companies reducing the number of trips to the field.

"I came across some video footage from drones at a drone film festival in London," she said. "There was a particular film that showed some of the Norwegian fjords from above that look spectacular. You could see beautiful fracture systems," she said.

So she thought that the ability to see geologic features from above, but also up close, as is only possible with drones, would give new insights from geological sites.

"I bought myself a drone. I learned how to create 3-D models using drone-mapping software, and created the Durdle Door model that you see. It was just beautiful,"

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she said.

Ruiz-Graham first came across virtual reality as a concept through news clips, she said. She thought she could create geologic field trips if she was able to bring 3-D outcrop models from drones inside virtual reality.

If people were not going to the mountains, she said, she could bring the mountains to them. She met her developer and the two started working together on the project.

As for the design, she said a key requirement was that the app should be able to reproduce high-resolution outcrop models. "If high quality was preserved inside virtual reality, then it would work," she said. "We did several trials until we got it right."

The first time she saw the high-resolution Durdle Door model inside 3D Gaia was very special for her, she said.

"It just looked spectacular," she added.

### Expanding the Tool Box

Another aim for her was to create tools that allowed her to do as a geologist what she couldn't do in the field, like drawing her interpretation directly over the outcrop or flying off the cliff. "I also wanted tools that allowed me to integrate subsurface data, so we built the seismic and well images viewer and the geomap that allows us to see geological maps in KML files," she explained.

Another key requirement was the ability to see satellite images inside virtual reality. The developer integrated Google Earth into the app, allowing users to fly over satellite images anywhere in the world.

Ruiz-Graham said she believes using such virtual reality will help increase team performance.

"Because this is very visual and you're really inside the image, as I said, I can fly, I can see the outcrop from very different locations. It's something that stays in your memory," she said.

It's also helpful preparation before a field trip. Users can learn about the destination through virtual reality and have a better understanding of the location once they are on site, she said.

It also allows everyone on the team to experience the location, as most field trips are limited in the number of people who take part.

"Usually you can't bring your entire team to the field," she said. "This way it creates a collaborative environment. You can access hard-to-reach areas that may be too expensive to get to. I can get as close to the outcrop as I want."

Another advantage to using virtual reality is knowledge capture, she said.

"When going to the field we take our notebook and video, but we are not able to repeat the experience. But with virtual reality you can," she said.

However, she's a firm believer that virtual reality should not replace field trips.

"I'm not saying virtual reality will replace field trips or should replace field trips, but it can open the possibility of more people seeing them. Not everyone gets to see the field. It opens the possibility to more people," she said.

She notes a few drawbacks to the technology, such as not being able to touch the rocks.

Still, she believes it's a tool that will help workers become more effective.

"I think it's going to make people learn better and have better ways of collaboration," she said.

## Transformation
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rudimentary agriculture, with a poorly educated, largely rural population plagued by poor health into a largely urban, relatively healthy population, including a large and prosperous, highly skilled middle class.

But, many were left behind and the dependency of the economy on oil rents grew rather than shrank over time. The famous call to "sow the oil," although accorded universal lip service, was never effectively achieved on a national scale.

The 1980s, however, produced an interesting and innovative experiment by one segment of the oil industry which showed that oil could be effectively and sustainably "sowed" within the existing socio-political framework during the more than 15 years of the program's existence from the 1980s to the 1990s.

But the eventual bitter clash in 1999 between the Venezuelan government and the state-owned oil company, Petróleos de Venezuela, S.A. (PDVSA) meant that the benefits to the poor majority of the population from greater access to oil revenues proved unsustainable. The conflict resulted in the mass firing of a large number of key oil workers and the diversion of a disproportionate share of oil revenues to support the political aims of the Bolivarian Revolution. Furthermore, rather than diversifying the economy, the redistribution of oil rents through "give-away" welfare schemes only increased dependency on this one revenue source with eventually devastating consequences for the Venezuelan economy as a whole.

In this context, the social investment experiment by Maraven was not meant to be a recipe for macroeconomic diversification or redistribution of income on a national level. But it did serve to demonstrate how the oil industry, or any large company, could work together more effectively with government and with its neighbors to improve basic living conditions and opportunities and thereby set the stage for bottom-up as well as top-down development initiatives.

Collaborative programs of this nature will be an essential element in any successful scheme to achieve a lasting and more just distribution of the nation's wealth.

# New Tech Promises 'Huge Impact' on Digital Rocks

By KEN MILAM, EXPLORER Correspondent

New developments in digital rocks and digital outcrop models continue to put more data – and more realistic data – on geoscientists' desktops.

X-ray computed tomography yields insight into rock microstructures. Tiny samples are scanned at high resolution and reconstructed as 3-D images, which can be used for virtual simulations and experiments to analyze the interaction of porous rock s with the fluids that flow through them.

On another scale, the use of aerial drones coupled with photogrammetry software to create virtual outcrop models to put fieldwork on the desktop (see related story on page X).


*This digital outcrop model of Upper Cambrian microbial reefs in Mason County, Texas, offer unique opportunities to assess varying scales for their spatial variation and potentially serve as subsurface analogs to improve reservoir correlation and modeling. Images courtesy of Rice University.*

"The impact of this technology is going to be huge," predicted Pankaj Khanna, a geoscientist and recent doctoral graduate in the Earth, Environmental and Planetary Sciences Department of Rice University.

"Building digital outcrop models is going to be the next basic understanding which every geologist would need to learn in the future. These models will be the future base maps for any geological studies," Khanna said.

"Already, many companies have started building their databases for 3-D digital outcrops, using them as base maps and populating data like well-logs, cores, seismic, measured sections, thin sections on top of the outcrops. As the world is getting technologically advanced day by day, I predict these digital outcrop models will be the next revolutionary step to integrate geology more with software, making it more hands-on and easy," he said.



## Synergy of Developments

Promising new developments include improved laws and regulations for flying drones, better and more inexpensive drones, improved processing software, and AAPG'S Digital Immersive Geoscience (DIG) program, which aims to promote publication of 3-D digital outcrop models, he said.

Khanna noted that a new fluid-lensing technique also allows researches to remove water from images of ocean and lakebeds taken at shallow depths.

Advantages of the technology include the potential to build in-house databases and in-field base maps, he said.

"The in-house database is a great tool to introduce students/geologists to the rocks by virtual field trips. This way, students in class at a university or industry could be informed and trained about the field area using digital outcrops. The training could be question specific – deepwater outcrops, carbonates, fluvial systems – and their morphologies and facies.

"The in-field base maps are a great tool to carry in the field where the students in training could see the rocks and at the same time look at the regional architecture of the field area/basin on iPads or phones, aiding in enhanced understanding of the subject," Khanna said.

He said upcoming challenges include development of a common, user-friendly database that could be accessed by all, perhaps through inexpensive subscription, and quality control.

"There need to be certain measures to be sure that the quality of the data is presentable," he said.

Peer review is a possible solution, he said.

Khanna said the technology is being applied to understand both modern and ancient systems in several areas around the world. North America and Europe are leading the way in geological studies utilizing drones.

"The discovery of hydrocarbon reservoirs in pre-salt microbial accumulations offshore Brazil and Angola,

Continued on next page

PROTRACKS

# Take Me Out to the Ballgame

By LAUREN STORM, AAPG Southwest Section YP SIG Member

In every downturn, companies position themselves for recovery by cutting exploration and decommissioning rigs, which in turn leaves thousands out of a job.

This holds true in Midland, Texas. Yet, amid one of the worst oil busts in decades, drilling has increased and the Permian Basin is busier than ever. Young professionals are slowly starting to trickle back into the area as job opportunities open up and companies prepare for a comeback.

And what better way to get Young Professionals involved in a new community than America's favorite pastime?

To start off a new year and get connected with other YPs in the industry, the Young Professional Geoscientists (YPGs) in Midland held an event at their local ballpark. The Midland Rockhounds, a minor league baseball team, played the San Antonio Missions on Aug. 31 in the last Thursday game of their regular season. Attendees were treated with a night of baseball and a picnic outing sponsored by the Southwest Section AAPG YP Special Interest Group (SIG). Space was limited to 25 guests – indicative of the slow comeback into the industry; but the YPGs have a positive outlook for 2017 and beyond.


STORM

This has become an annual event for the YPGs as a way to start the New Year, and it's only the beginning. The West Texas Geological Society (WTGS), consisting of members from the petroleum and environmental industries as well as academia, hosted their annual Fall Symposium Sept. 27-29. The YPGs held a happy hour event to encourage students, unemployed graduates and young professionals to seek advice about career paths, build professional networks and to interact with established members of their local geological community. Along with several other conferences scheduled through the year, the group is planning (pending additional sponsorship) field trips to local geology sites, potlucks and holiday parties, as well as activities like a 5K run and volleyball tournament.

With the positive turnout from their recent event, it might just signal that there are brighter times ahead for the Midland oil and gas industry.

Continued from previous page

in addition to a significant microbial component in some of the world's largest carbonate reservoirs in the pre-Caspian Basin, has renewed interest in microbial deposits. Spectacular outcrops of upper Cambrian microbial reefs in Mason County, Texas, offer unique opportunities to assess varying scales of their spatial variation and potentially serve as subsurface analogs to improve reservoir correlation and modeling," said Khanna. "I have built digital outcrop models of these upper Cambrian reefs and conducted qualitative and quantitative spatial statistical analysis to understand their spatial architecture and heterogeneity."

### Big Data Sharing

At the micro level, digital rock physics complements the laboratory and field work that geologists, petroleum engineers, hydrologists, environmental scientists and others traditionally rely on. Last year, the Texas Advanced Computing Center at the University of Texas in Austin launched the Digital Rock Portal, where researchers can store, share, organize and analyze the structures of porous media using the latest technologies in data management and computation. The project was funded with a National Science Foundation grant as part of EarthCube, a large NSF-supported initiative that aims to create an infrastructure for all available Earth system data to make the data easily accessible and useable.

Because the volume of data that can be derived from one tiny sample can be huge, files can be too large for most email servers and the storage requirement for companies can become a challenge.

The portal offers exploration companies free and unlimited data storage in exchange for making their computed tomography (CT) images of rocks available to outside researchers.

The platform allows managing, preserving, visualization and basic analysis of available images of porous materials and experiments performed on them, and any accompanying measurements (porosity, capillary pressure, permeability, electrical, nuclear magnetic resonance and elastic properties, etc.) required for both validation on modeling approaches and the upscaling and building of larger (hydro)geological models.

### BP's Digital Rocks Program

BP established its own proprietary digital rocks program 10 years ago using rock core samples acquired from exploration, appraisal and development wells.

The algorithms that simulate the physics necessary to characterize rock properties are run at BP's Center for High Performance Computing in Houston, one of the largest supercomputers in the world dedicated to commercial research.

BP has applied the technology across the globe, including fields in Angola, the Gulf of Mexico, the North Sea, Egypt, Azerbaijan, the Middle East, India, and Trinidad and Tobago.

The company recently announced a new multi-year commercial agreement with Exa Corp., which will enhance BP's ability to predict the flow of oil and water in digital images of reservoir rock.

The company announced that new multiphase flow simulation technology will help engineering teams to make more informed decisions on wells, production facilities and resource progression, including enhanced oil recovery.

Exa's multiphase fluids simulation solution for digital rocks was co-developed with BP during a three-year technology collaboration agreement.

"After years of cooperative research and development, this breakthrough represents an important step forward for BP and for our industry," said Ahmed Hashmi, BP's head of upstream technology.



# 40th Annual Trustee Associates Meeting

By DIANE KEIM, AAPG Administration and Programs

The AAPG Foundation Trustee Associates gathered in September at the beautiful Samoset Resort in Rockport, Maine to celebrate both the Foundation's 50th anniversary and the 40th annual meeting of the Trustee Associates.

Despite the distraction of this gorgeous setting, the group was able to conduct two business meetings to learn about Foundation business and activities, which included the election of new officers. David Hawk was elected as the new chair, Pete MacKenzie as vice-chair and Bill Monroe will serve a two-year term as secretary/treasurer.

Greeted by fall's first blush, the group tested brisk north winds on the top of Mt. Desert in Acadia National Park on the field trip lead by Stephen Norton, distinguished professor and professor emeritus, and Sam Roy, postdoctoral research associate, both with the University of Maine. Along with stunning views of the park's mountains and cliffs, with stops at Sand Beach and Jordon Pond, the group enjoyed lunch in the bayside town of Bar Harbor.

Smaller groups had the opportunity to enjoy a variety of Maine's special offerings. like a privately chartered sail in Penobscot Bay, a wine-paired lunch and tour at Cellardoor Winery, a trip to downtown Rockland for a visit to the Maine Lighthouse Museum, followed by a turn on a lobster boat as participants tried their hand at lobstering, and fishing on Megunticook Lake. Not to be outdone, the golfers spent two days at the Samoset Resort Golf Club experiencing New England's premier championship course.

The meeting concluded at the Owl's Head Transportation Museum with the Farewell Reception and Awards Dinner where they dined amongst Formula One racers and other exotic cars for a night to remember. Guests had the opportunity to walk among a world-famous collection of pre-1940 aircraft, ground vehicles, engines and related technologies that were significant to the evolution of transportation. The evening closed with the presentation of the golf and fishing awards involving a few tales of the 'one that got away.'

Special thanks to David and Bev Worthington for sharing their home community with the group and selecting this wonderful location for the meeting.

There was much laughter as the meeting came to an end and everyone said goodbye until next time. With the end of this meeting comes anticipation for the 41st annual Foundation Trustee Associates Meeting to be held at Sun Valley Resort in Sun Valley, Idaho. Next year's program promises to be impressive with the Sun Valley Resort's Ice Show kicking off the meeting on Aug. 11, 2018.

The Trustee Associates are vital to the success of the Foundation and their annual meeting provides an opportunity to stay current on Foundation business while building long-lasting friendships. Recently, the AAPG Foundation Trustees approved a reduction in the fee to join the Trustee Associates from $15,000 to $10,000. Should you want to learn more about this great opportunity and receive information about the Trustee Associates program, please contact Tamra Campbell at tcampbell@aapg.org or 918-560-2644.

## Other Foundation News

The AAPG Foundation Grants-in-Aid and L. Austin Weeks Undergraduate programs are now accepting applications. These programs provide grants to qualified students ranging from $500 to $3,000 to assist with their educational endeavors. The Foundation is also accepting nominations for the Teacher of the Year program, which recognizes outstanding K-12 educators. Please visit the Foundation website (foundation.aapg.org) to see how your financial gifts can benefit these programs.

## EMD
from page 30

technologies, presents an interesting component in our learning curve equation. When combined with the energy needs of space and deep ocean exploration, unique military requirements or in distributed energy scenarios, our learning curve changes.

Finally, the global need, as expressed though the global political and philosophical system, is for universally distributed and readily available, efficient and inexpensive energy. This factor can drive our learning curve from linear to exponential, or geometric. Our first and second considerations are increasingly being informed, guided and driven by this thought.

### Incline Ahead

As EMD, or even as AAPG, where are we on this curve now? What is the shape of our forward-looking learning curve? Considering the developments associated with non-conventional oil and gas, new technologies developing in renewables, new scale concepts in nuclear, plus the growth in the technologies associated with energy distribution and storage, I believe we have just passed an inflection point and that a spectacular, non-linear growth has begun. Technology and innovation is moving fast. Our learning curve could be geometric or exponential but I do know it will be steep. New ideas and approaches will keep us fresh and growing. We are good climbers!

### Foundation Contributions for September 2017

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

DIRECTOR'S CORNER

# Closing Out the Centennial with an Inspirational Conference

By DAVID CURTISS

The sun shone on London in mid-October as AAPG continued its centennial celebration with our final major event of the year at the 2017 International Conference and Exhibition (ICE).

And that shining sun was a harbinger of a great conference, as more than 2,000 attendees from across the globe gathered to teach and learn about the science, the industry trends, and catch a glimpse of the future of the next 100 years of oil and natural gas exploration.

Inspiration is what many of us were seeking in London, and the opening ceremony, themed "Inspiration from Exploration," did not disappoint, beginning with an uplifting musical medley presented by students from the Sylvia Young Theatre School and a welcome from ICE 2017 co-chairs Gabor Tari and Ken McClay and opening remarks by President Charles Sternbach.


CURTISS

> **Exploration requires new and different kinds of thinking. It requires folks who don't all think the same way.**

## Europe Awards

Recognizing excellence is one of the most important things we do at AAPG, and taking advantage of ICE being in London this year, the AAPG Europe Region leadership established and bestowed a series of AAPG Europe Awards, presented by AAPG Europe President Fiona MacAuley to:

- Luca Bertelli, the chief exploration officer of Eni Upstream and Technical Services, who received the AAPG Europe Explorer of the Year Award.
- Prof. Reinhard Sachsenhofer of Leoben University in Austria who was recognized as AAPG Europe's Educator of the Year.
- Prof. Brian Horsfield of GFZ Potsdam and the University of Berlin who received the AAPG Europe Energy Geoscience Research Award.
- Victor Vega, exploration new business development manager for Shell Americas, who was recognized for his dedication and commitment to public service and inspiring others to engage in such activities with the AAPG Europe Public Service Award.

## ICE Highlights

Jonathan Craig, the Honorary Chair of ICE 2017, then introduced the two keynote speakers of the evening: Lord John Browne of Madingley, business man and former group chairman of BP, who spoke about the future of energy, innovation and energy transformations. He was followed by planetary geoscientist Dr. Kirsten Siebach, who took us out of this world for a sedimentological and stratigraphic journey around Mount Sharp, talking about the excitement of exploration – exploration on Mars.

Buzzing and bustling is the only way to describe the icebreaker reception in the exhibition hall that kicked off the social and networking activities at ICE 2017. As attendees walked the aisles of the exhibition they were treated to libations and refreshments amid the booths of oil companies, service companies, and a particularly vibrant International Pavilion.

On Monday the technical program began with an Executive Plenary session chaired by Pinar Yilmaz. This thought-provoking plenary was themed "100 Years of Science Fueling 100 Years of Prosperity" and included:

- Michael G. Cousins, executive vice president of ExxonMobil Exploration Company.
- Adif Zulkifli, senior vice president of development and production upstream business for PETRONAS.
- Ibraheem Assa'adan, vice president of exploration for Saudi Aramco.
- Luca Bertelli, chief exploration officer of Eni Upstream and Technical Services.
- Mario Carminatti, exploration executive manager for Petrobras.

A recurring theme during the plenary session was that geoscientists need to understand both sub-surface risks – their natural forte – and above-surface risks. It's not enough to simply find oil and natural gas. You've got to find it in places where it can be commercially produced. And this basic truth needs to be taught to students, not just professionals.

There was also concern that technology and research and development are the first casualties in any market downturn. And yet they are precisely what also lead us out of a market downturn. As a result, we're not learning fast enough – the industry needs to do better.

## Technical Program

Following the Executive Plenary the technical program began in earnest, with oral and poster sessions across 12 different themes. The program also included several special sessions, including a packed Discovery Thinking session – now in its 10th year – co-chaired by President Sternbach, past President Paul Weimer and AAPG Europe past President Jonathan Craig and included presentations on the Goliat (Norway) and Zohr (Eastern Mediterranean) discoveries, as well as Senegal and the East African rifts. The conference also included a session on landmark discoveries of the last 100 years.

Exploration was a dominant theme at this conference. But as the executives in the plenary session pointed out, exploration requires new and different kinds of thinking. It requires folks who don't all think the same way. An effective exploration team requires diversity of backgrounds, experiences, and beliefs.

And two of the ICE 2017 sessions focused on these issues. First, there was a special session on the "Bottom-line Benefits of Diversity" (coverage of which will appear in the December EXPLORER), which discussed how diversity affects decision quality, recognition and rewards and cultural overprints. In addition, an evening panel discussion entitled "Leadership – Technically-Adept and Business-Savvy in the Petroleum Industry," moderated by President-elect Denise Cox, explored what it takes to be an effective leader in the petroleum industry.

ICE 2017 was a fantastic event, made possible by the dedication of our leaders, members, and volunteers, our sponsors and exhibitors. I'd also like to recognize our staff's efforts to ensure this was a successful conference. Congratulations and thanks to all.

DIVISIONS REPORT: EMD

# Viewing the Future from a 40-Year Past

By DOUG WYATT, EMD President

The Energy Minerals Division was organized in 1977 as an international forum for those working in the exploration, development and production of energy sources other than conventional oil and natural gas. Our purpose then, as now, is to serve the AAPG by advancing the science, energy economics, technology and geology as it relates to energy resources other than conventional oil and gas. These include uranium and nuclear minerals, coal, coal-bed methane, lignite and other carbon minerals, geothermal energy, gas hydrates, unconventional hydrocarbons such as shale gas and liquids, oil shale and oil sands. As the concepts of blended energy resources and energy portfolio economics developed, we added wind, solar, tidal, biomass and other renewable resources to our content of support to the AAPG. This is what we have done in the past and what we do now, and we continue to do it all very well.

However, any intelligent and growing organization continues to seek and search and ask the questions of: "What is our next and best step?", "How do we grow?" and "What future must we support?"


WYATT

> **I believe we have just passed an inflection point and that a spectacular, non-linear growth has begun.**

## Learning from the Learning Curve

I am a student of, and fascinated by, the learning curve. You might be too. Simply put, a learning curve is a graph representing the principle that the more you do something, the better you become at it. Or, maybe better stated – the more skill and knowledge you develop, the greater that skill and knowledge develops. It is a graph, often with a linear, geometric or exponential growth rate. These curves, and the math that goes with them, are very useful in determining technological or institutional growth and in predicting a point in the future. I use them often in the development of research scope and technology development. They are very useful in looking back to where we have been and forward to where we want to be, all given the growth of the associated knowledge and technology associated with our mission.

Consider the growth in the technology, engineering and science of the oil and gas industry, and the overall extractive energy minerals industry. Consider the growth in the world energy demand, the need for supporting resources for efficient energy utilization and in the politics and philosophy of global energy. Can we factor all of the various learning curves generated from these areas into a curve that can inform and help us for the next 40 years? I think so.

First we must consider the overwhelming and growing change from a global long-chain hydrocarbon to a short chain and molecular hydrocarbon market. Much of the science and technology, as well as the global political and philosophical discussion, involve this change. Although conventional and unconventional oil, as well as coal, are global staples now, their use in the future will diminish as methane use from shale or hydrates increases. These factors contribute to our learning curve.

Second, the wise need for a mixed energy portfolio, both from an economic and financial perspective, an environmental perspective, bespoke needs, as well as an energy security perspective, will demand the use of geothermal, nuclear and surface process energy sources such as solar, wind and tidal energy. The mix, and the technological merger of these

See EMD, page 29