JANUARY 2017 | 100 AAPG ANNIVERSARY

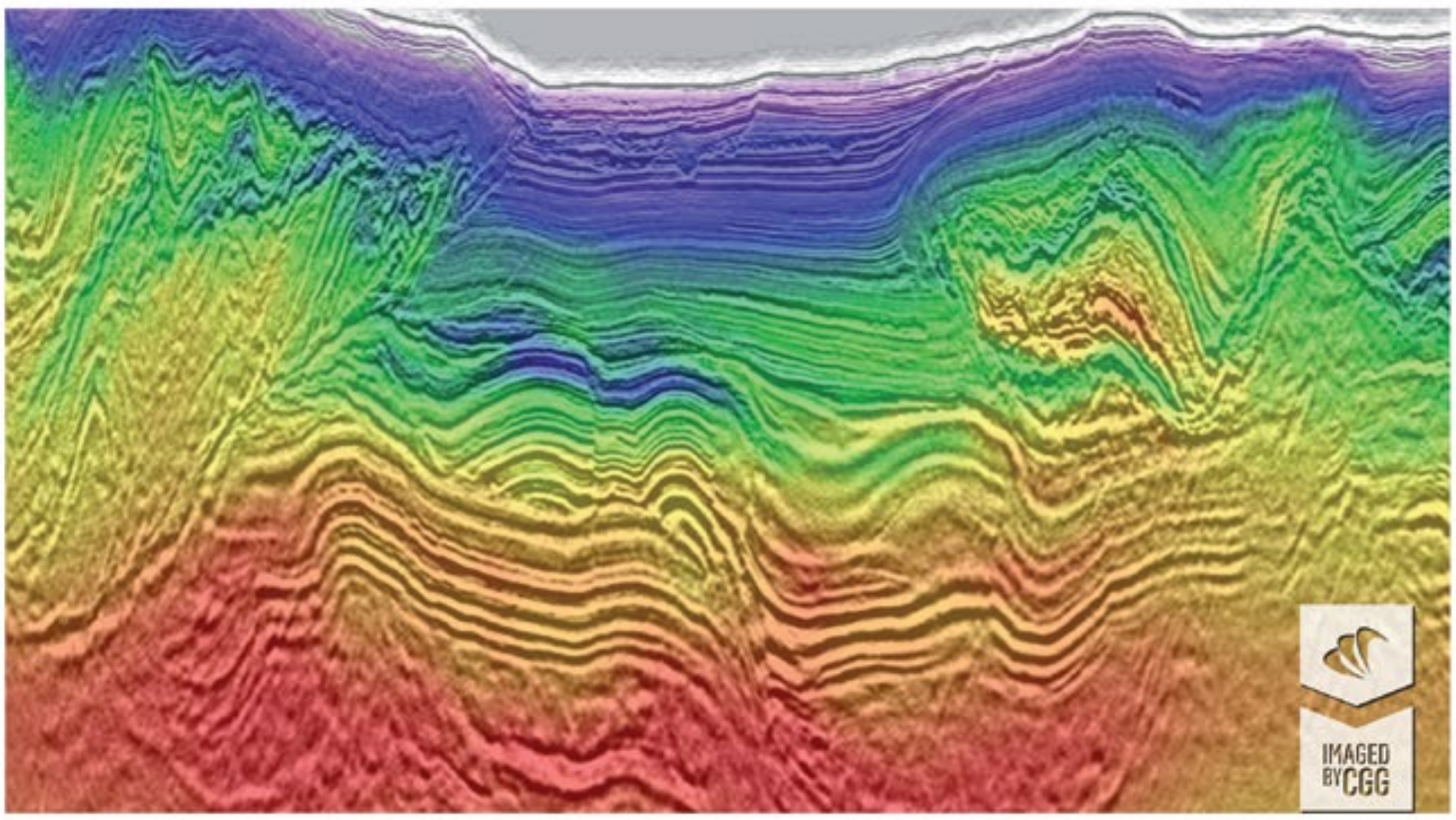
EXPLORER

Future Forward

AAPG celebrates the next century of exploration and discovery.

PRIME PROSPECT

Mexico Encontrado
Wide-Azimuth Reprocessing

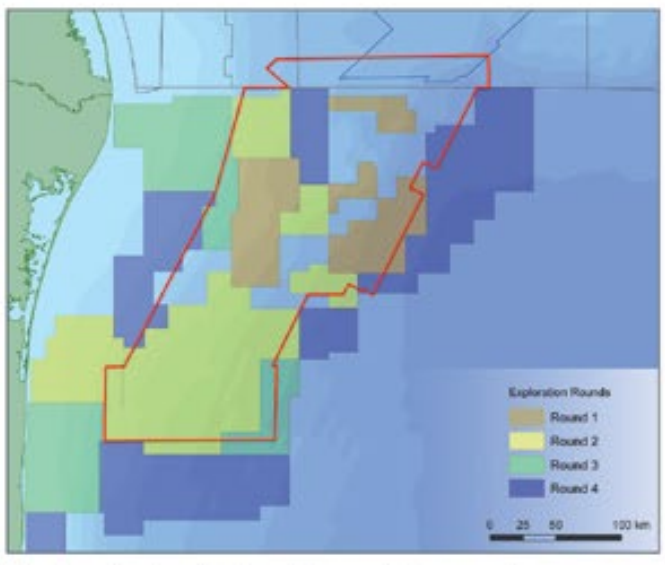


FWI resolves complexity of the Salt Front Thrust Belt.

Encontrado is an extensive wide-azimuth survey of over 38,000 km² in the Perdido fold belt, covering many of the blocks in the current and upcoming Mexico licensing rounds, with early-out RTM data available in February 2017.

It is currently being reprocessed through a state-of-the-art high-end sequence, including 3D deghosting, 3D SRME and advanced imaging, with multi-layer tomography and FWI velocity modeling.

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



Map showing Encontrado outline and the current exploration rounds.

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Passion for Geoscience

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PRESIDENT'S COLUMN

Being Part of the Conversation

BY PAUL BRITT

When it comes to politics, there seems to be some confusion among Members regarding the differences between *politics*, *policy*, *advocacy* and *legislation*.

"Legislation" is the act of setting the rules (laws) that govern business and personal behavior. "Advocacy" is the action of promoting a particular interest or result in legislation. "Policy" is the underlying facts, theories, opinions and philosophical considerations that go into legislation. "Politics" is the art of structuring and organizing personal and institutional actions to accomplish these objectives and to arrive at a consensus.

The distinctions are important to delineate because our Members have often expressed the opinion that as scientists, AAPG has no place in policy or politics, frequently conflating the two. Politics includes advocating a position in any situation, and we as AAPG do not – and should not – advocate political positions that might benefit one Member's interests over another's. The proper channel for that is in our personal realm of influence, by contacting our representatives (in the case of U.S. Members, at least) at the local, county, state and national levels. There are advocacy groups, trade associations and other affiliations designed specifically for that purpose, which our Members can join if they choose.


BRITT

> **Silence is not a virtue when it comes to carrying the scientific message.**

Applying Science to Policy

I would argue, however, that as scientists, we not only have an interest, but an obligation to ensure sound, rational science is applied in the course of public policy. Members of Congress are under a constant barrage of lobbying efforts from various advocacy groups – some masquerading as policy groups – in order to influence the direction of legislation. Senators and representatives and their staff usually do not have a background in science nor do they have a great deal of time to spend trying to wade through the morass of websites, publications and materials with which they are bombarded by advocacy groups in order to determine what is scientifically logical and sound.

They might, however, and have in many cases, sought information from scientific groups like AAPG on many topics. Our presence in Washington, D.C. over the last 10 years has established many relationships to which AAPG has been a source of scientific background. They have participated in briefings and committee hearings to provide factual information to policymakers and have arranged "lunch-and-learn" talks for staffers with subject matter experts (SMEs) from AAPG. Frequently, when science information is sought, the timeline in policymaking is minutes or hours – days are considered a lifetime in D.C.

At the Geo Congressional Visit Days hosted by the American Geosciences Institute last September, a staffer from outgoing Rep. Mike Honda's (D-Calif.) office spoke to the group. He said they welcome input from geoscientists and admitted that, since they heard so infrequently from geoscientists, there was no geoscience "checkbox" on their call-in list, and frequently those calls were allocated to "other," along with random calls and "crazies."

The essence of the conversation was that you have to participate in the conversation if you want your knowledge included in the process.

Frequently Asked Questions

- AAPG has Statements on topics that are of particular interest to our Members (formerly called "Position Statements," but it was felt by some that the word "position" was too strong). However, these Statements are essentially equivalent to a Frequently Asked Question (FAQ) and outline *positions* regarding geoscience.
- These Statements are available on AAPG's website and serve to explain to the public our position or view on those subjects to which we can speak, as scientists, in terms that target the public. They are fairly general in nature due to the spectrum of opinion and interest among the AAPG Membership, but serve as an important vehicle in communicating with elected officials and the public at large regarding topics of interest to our Members. These are aligned with our second and fourth bullets of our Mission Statement as: "to promote the technology of exploring for, finding, and producing these materials in an economically and environmentally sound manner" and "to disseminate information relating to the geology and the associated technology of petroleum, natural gas, other subsurface fluids, and mineral resources."

Maintaining a Presence

As many of you already know, I have always been an advocate of AAPG's "GeoDC" Geoscience and Energy Policy Office. However, due to the continued oil price slump and resulting industry downturn, we have had to eliminate the staff support in Washington for this activity. AAPG will remain engaged in Washington, but the duties will be manned by volunteers while we evaluate our next steps.

All of the examples in this column are about the office in Washington, D.C. but the principles apply in any local or international venue where citizens are able to have a voice. Silence is not a virtue when it comes to carrying the scientific message. And the fact remains: if you want to be part of the conversation, you have to be present – and engaged.

(Editor's note: See Policy Watch on page 28 for more details about how to engage your representatives your local, state and national legislatures.)

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REGULAR DEPARTMENTS

ON THE COVER:

The view south toward Brooks Range of shoreface and deltaic deposits in the Nanushuk Formation at Tuktu Escarpment, about 140 miles southwest of Prudhoe Bay. River bluffs in the distance are marine slope and basin-floor fan deposits in the Torok Formation. The Nanushuk and Torok formations contain stratigraphic traps like those recently discovered by Armstrong and Caelus. See story on page 12. Photo courtesy of David Houseknecht.

Left: Local Turkana women retrieve water from a scoop hole likely contaminated with E. coli. Providing clean water to areas like this is one of the numerous humanitarian projects by Geologists Without Borders. See story on page 6.

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Be a Judge at ACE 2017

By MEAGAN WALL and MEREDITH FABER, ACE 2017 Judging Committee


WALL

We need everyone's input to pinpoint groundbreaking ideas and identify gifted speakers who might otherwise be lost in the shuffle.


FABER

For every poster and oral session you visit during your time at the 2017 Annual Convention and Exhibition (ACE), there will be a judge nearby. AAPG judges play the critical role of finding the most ingenious studies and applications in petroleum geology. It's the judges' responsibility to determine which new technologies are the most imaginative, which methodologies are most logical and repeatable, and which oral and poster presentations deserve to be celebrated by being awarded the George C. Matson Award (for best oral presentation) and the Jules Braunstein Memorial Award (for best poster presentation).

In advance of the meeting next April, the ACE 2017 Judging Committee would like to bust a few myths about the judging process and encourage everyone who plans to attend the meeting to sign up to be part of the team.

▸ Myth 1: "I'm not qualified to be a judge."

Reality: Many conference goers have expressed concern that they're not qualified to judge because they're not a subject matter expert. The reality is that anyone can be a judge. Whether you're a Student, an Associate, a Member or an Emeritus member, all you need is a willingness to critically evaluate the material being presented and the ability to see how the ideas would advance our science.

▸ Myth 2: "My conference schedule is so busy, I won't have time to judge."

Reality: There are hundreds of oral and poster sessions during ACE, occurring both in the morning and afternoon. The best way to help with the judging effort is to offer to judge the sessions you'll already be attending. Even if you don't have a particular session in mind, we can help you find which part of the technical program will work with your schedule. Volunteers are welcome to judge as many or as few sessions as they'd like.

▸ Myth 3: "ACE Houston is a big meeting. There will be enough volunteers to judge."

Reality: There are never enough judges! More and varied opinions lead to better results. We need everyone's input to pinpoint groundbreaking ideas and identify gifted speakers who might otherwise be lost in the shuffle. On average, each session at ACE will secure one to three judges, but a program as robust as ACE really needs five to seven judges per session.

▸ Myth 4: "The judging forms are complicated."

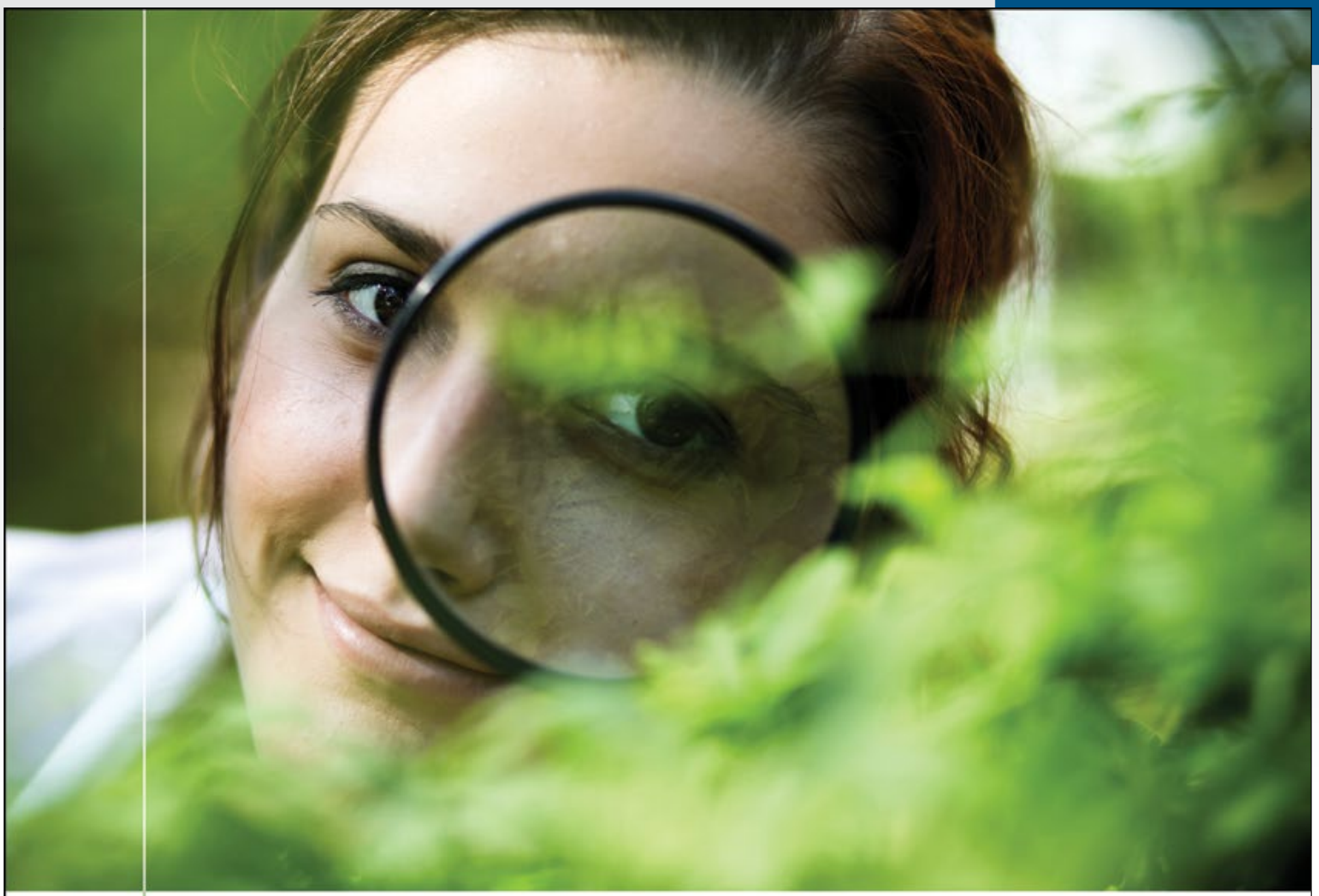
Reality: The judging criteria have been streamlined over the past few years and the forms are easier and less cumbersome to complete. Guidelines and suggestions for our numerical scoring process have been created to keep you from getting bogged down in comments and notation.

▸ Myth 5: "Judging might restrict my ability to make connections at the meeting."

Reality: Whether this is your first AAPG meeting or your 30th, it can be extremely difficult to find a way to approach someone who might be a crucial component to your network. Whether you're looking for a job, a client, a connection or even to make a social connection and find new friends, the process can be exhausting. Judging offers a means to alleviate those social pressures by guaranteeing a level of interest and dedication of attention that can and does forge new relationships.

Being a judge at any AAPG meeting is a rewarding experience that not only can expand your professional network, but also your scientific horizons. It's also a moment of philanthropy taken on by those with the insight and selflessness to identify the quality, thought and ingenuity in others. We hope you'll sign up to be part of the team, but if you're still unsure, or have questions about the process, contact Judging Chair Meredith Faber at meredith.faber@nblenergy.com.

See you in Houston!



Crossing Borders to Change the World

By BARRY FRIEDMAN, EXPLORER Correspondent

Think of it as kinder, gentler, altruistic geology.

"There's a refugee camp in Kenya. There are 300,000 people there and there's a serious water problem and when you think about it, through much of the world, people live on about four gallons … and that takes about as much time (to use up) as it does to brush your teeth."

That's AAPG Emeritus Member Robert Merrill of Catheart Energy, Inc. talking about some of the projects of Geoscientists Without Borders (GWB), a humanitarian program that supports humanitarian applications of geoscience around the world.

Merrill, who represents the AAPG Foundation on GWB's technical committee, said the organization's mission is about solving problems in areas that need help – like those water problems, but also earthquake and tsunami warning and flood preparedness. In addition to those humanitarian efforts, the organization strengthens the global geoscience community through beneficial multidisciplinary partnerships worldwide and by encouraging student involvement.

And when it goes well – and it's often a slow, frustrating experience – GWB leaves a legacy in place.

Which is also the point.

"GWB supports initiatives around the world that focus on, number one, solving problems, number two, educating students and getting them interested in geoscience, and number three, making it possible to engage their local population in the results," said Merrill.

Volunteer geophysicist Randy Shundike and Katila and Odonga, students in IsraAID's WASH program, run the ABEM LS system for resistivity imaging near Kaolobeyei. Photo courtesy of GWB.

The organization, which is administered by the Society of Exploration Geophysicists, began in 2008. Schlumberger was its founding supporter and the AAPG Foundation has been a GWB Associate supporter for the past two years.

Project Submission

Here's how it works.

After requests are made by host countries (usually from scientists and geologists within afflicted areas) to universities in the United States, Canada, Europe and Australia, those schools then petition GWB, which then decides which are most feasible and where GWB can do the most good. Once a project is approved, it can take up to two years to complete.

"We are really dependent on organizations submitting projects and most of these projects are from around the world," Merrill said.

But that is often just the beginning.

"Once a project has been approved, there's a negotiation involved to make sure the money is handled appropriately."

It's important to GWB that the afflicted areas get as much bang for the buck as possible – and these projects can cost as much as $500,000.

"We make sure the grants do more than just pay administrative fees. We're not looking for projects where we're just buying computers," said Merrill.

At the moment, while projects from Honduras, Romania, India, Thailand, Jamaica and South Africa are still in progress, Merrill said GWB can report on the following.

Peru

A permanent monitoring and early warning system is being established to track the evolution of the Maca landslide, located in a high seismicity region (next to Arequipa). Landslides there threaten a village of 900 inhabitants, a very popular and frequented road (500,000 vehicles a year) and pre-Inca terraces. The goal here, Merrill said, will be to equip the region with up-to-date geophysical instruments to track the landslides, including GPS, seismometers, piezometers and a meteorological station, ultimately developing an alert system for landslide activity in case the mass starts moving again toward the village.

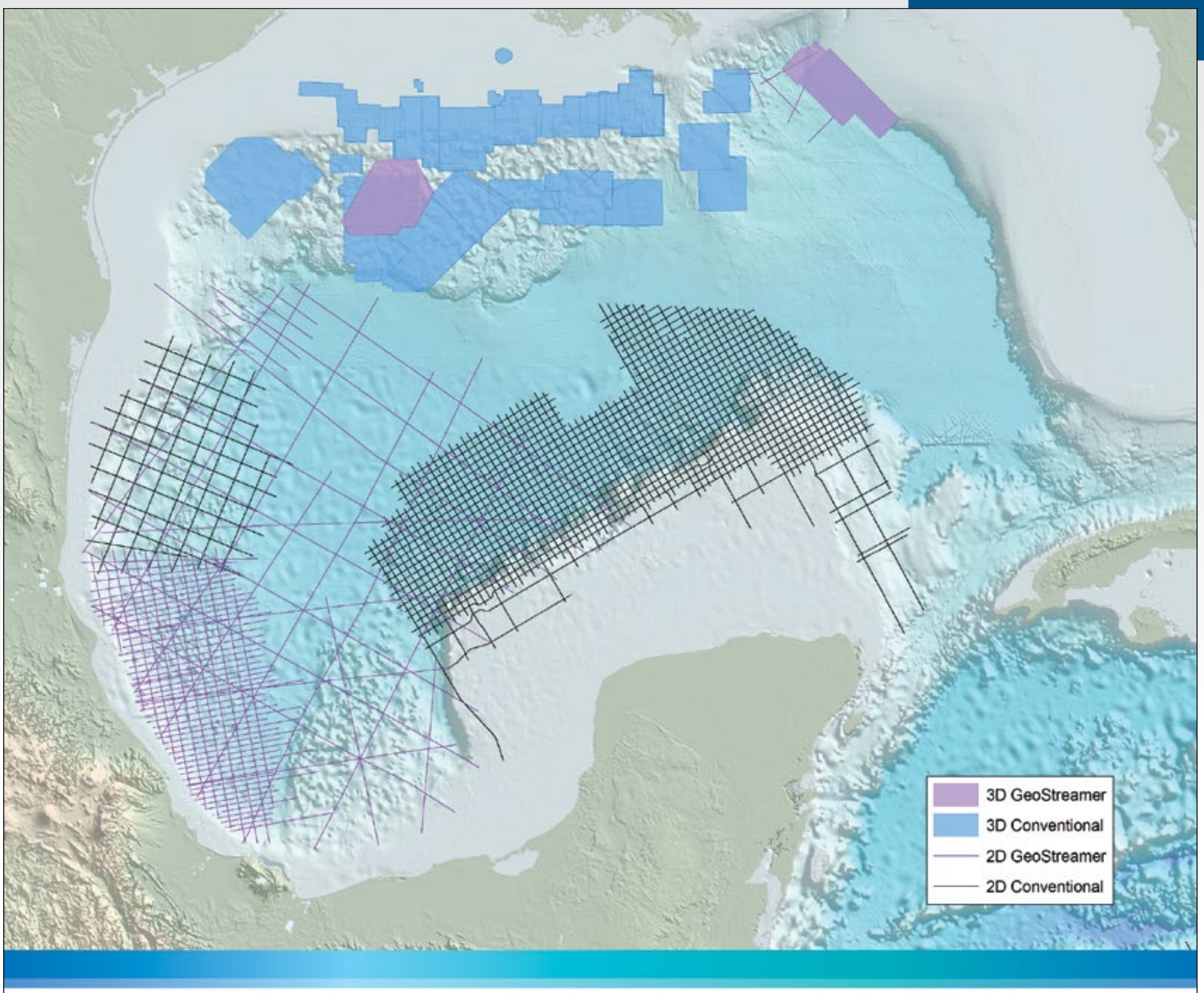
Indonesia

Here the efforts are to develop tsunami inundation maps for the south coast of Java to be used to implement disaster prevention strategies, such as evacuation drills. Historical records compiled of the area indicate this region of the country has been hammered by tsunamis for the past 430 years.

Kenya

After a GWB grant was awarded to IsraAID, a project at the Kakuma Refugee Camp in northwestern Kenya identified

See **Wells**, page 15



Year of Discovery Sees 'Dim Bright Spots'

By DAVID BROWN, EXPLORER Correspondent

Leave it to the experts to sum up what the international exploration picture looked like in 2016:

"Not much," said Pete Stark, senior research director and adviser for IHS Markit Ltd.

By one measure, 2016 shaped up to be the worst time for international oil and gas discoveries in years.

By another, last year looks like the worst for international oil additions in decades.

"The decline in global discoveries are ongoing from 2015," Stark said. "By the end of November, we were looking at just 7 billion barrels of oil equivalent, slightly biased toward gas."

Consider this: the world's two biggest discoveries last year were both in the United States – the Caelus Energy LLC oil discovery at Smith Bay on Alaska's North Slope, and the Apache Corp. Alpine High oil and gas find in the southern portion of the Delaware Basin in Texas.

IHS includes frontier U.S. discoveries like Smith Bay in its year's best wells list, but not onshore Lower 48 plays like Alpine High, which Stark said "is really back in the shale game again in West Texas."

That makes the 2016 exploration highlights list even less exciting.

The Caelus Energy Alaska find turned out to be the year's big, exciting oil discovery. Without that well, natural gas would have been "super-dominant" in the resource total, Stark noted.

"It's that one U.S. North Slope discovery that makes oil look a little better, that breathes life into it," he said.

Discovery in Decline

And once again, offshore wells dominate the year's best discoveries, many of them in deepwater, Stark said. That's also been an ongoing trend in international exploration.

A nasty downturn in the oil and gas industry over the past two years slashed the number of rigs drilling wildcats worldwide, contributing to the decline in exploration successes. "It's the post-recession lower oil and gas prices," Stark said.

But while the industry slump and lower prices in recent years have hurt international exploration efforts, they can't be blamed for the overall trend. The decline has persisted year after year.

"It's a continuation of the slide in international discoveries that has been going on since 2010," Stark observed.

International exploration results have disappointed in size for some time. But the decline in number of successful exploration wells is truly startling, and the discovery rate also "has tended to be on a downward slope," he noted.

"If you look back a decade ago we were averaging in the neighborhood of 450-500 international discoveries a year," Stark said.

When the final results for 2016 are totaled up, he expects – maybe – a little over 200 successes.

Overall, international natural gas discoveries weren't bad in 2016, but "it looks like oil could be at the lowest level since 1952," Stark said.

International Ennui

Back to last year's dearth of big discoveries outside the United States – some of that comes from the industry downturn, some from geopolitics. And some can be blamed on a corruption scandal and political upheaval in Brazil, usually a contributor to the big-success list.

"Internationally, outside the U.S. you've had one giant discovery, in Senegal," Stark said.

"West Africa is still producing a few good discoveries. The rest is scattered. There's nothing in Latin America, mainly because of Brazil," he added.

It might be a dim bright spot that international exploration success was spread around the globe in 2016. Turkmenistan claimed added resources, and Myranmar upped reserves with a good discovery well.

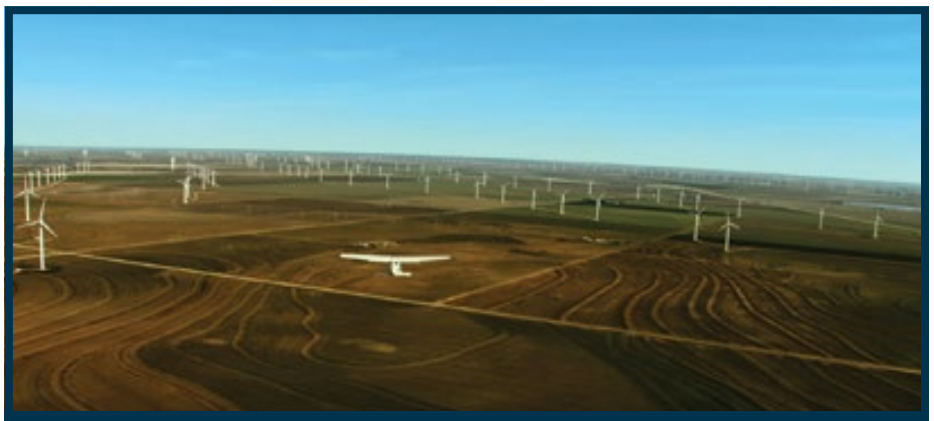
"There was one in Romania, but it was mostly gas. PetroChina had a similar one in the Tarim Basin, and that's only one of two in the Far East," Stark said.

In the IHS preliminary list of best international discoveries last year, only seven seemed to have a chance to reach or exceed the 200 million barrels of oil equivalent threshold:

- Alaska North Slope

Caelus Energy Alaska LLC, Smith Bay, Tulimaniq No. 1 and 2 wells, 1.8 billion barrels of oil and 1.8 trillion cubic feet (Tcf) of gas

See **Threshold**, page 14



Flying over Roscoe, the largest wind farm in the world. Images courtesy of Switch Energy Progect.

A mine in the Power River Basin, the largest coal reserve in the world.

Energy in the Next Century

By DAVID BROWN, EXPLORER Correspondent

If you want to talk about the future of energy into the next century, you have to talk to Scott Tinker.

Tinker might have the best overview of energy on the planet.

He serves as director of the Bureau of Economic Geology at the University of Texas-Austin and as a professor in the university's Department of Geological Sciences.

He is the state geologist of Texas.

He lectures and consults on energy matters worldwide.

He's a member of numerous energy-related private, public, academic and government boards and councils.

A past president of AAPG, Tinker was the 2016 recipient of the Association's Michel T. Halbouty Outstanding Leadership Award, along with a litany of other awards and honors. He also has led the Association of American State Geologists, the Gulf Coast Association of Geological Societies and the American Geosciences Institute.

Tinker is particularly renowned for having founded the Switch Energy Project.

That project produced the award-winning, 98-minute, 2012 energy documentary "Switch," directed by Harry Lynch, which has been seen by more than 10 million people.

For the few who haven't seen it, "Switch" chronicles Tinker's travels around the world to investigate energy sources of all types, including the Big Two – crude oil for transportation and coal for electricity – that provide a majority of the world's energy today.

In the end, "Switch" projects that in about 50 years, the share of world energy produced from oil and coal will be equaled and then surpassed by the total energy from natural gas, nuclear, hydroelectric, wind, solar and other renewables.

That switchover would mark a notable change in the world's energy supply.

That was the prediction five years ago.

What is the outlook now?

So far, Tinker said, the world is following the path of energy usage envisioned in the documentary.

"That general energy mix is pretty close to on track," he said.

"Coal has remained higher in the mix than I thought it would. People on the street might not believe it if you told them, but coal keeps going up worldwide in the global mix," Tinker noted.

In the "Switch" scenario, crude oil and coal should continue to provide a significant share of the world's energy. That share is expected to fall below the 50-percent mark later this century.

Factors of the 'Switch'

"It's hard to imagine a world that doesn't have transportation fueled by gasoline, diesel and jet fuel," Tinker said.

TINKER

Scott Tinker will be among six speakers at a forum at AAPG's centennial Annual Convention and Exhibition in Houston in April, organized by AAPG's Division of Environmental Geosciences and the Energy Minerals Division. "The Next 100 Years of Global Energy Use: Resources, Impacts and Economics" will be the title of his presentation.

Those liquid fuels are so efficient and so dense that replacing them will be a tremendous challenge. Alternatives are slowly emerging, but have challenges of their own. For instance, a battery in an electric car is three times the size of a gas tank and you can't travel nearly as far, Tinker observed. And that battery still needs to be charged. The electricity fuel mix varies regionally, but still has a lot of coal in it.

What could make a difference are changes in behavior. One example would be the movement toward electronic/virtual meetings and communications instead of physical travel. Telecommuting for work is increasing.

Also, Uber's reach is spreading, so millennials today no longer feel they have to own a car.

Those kinds of social changes will have an impact, Tinker believes.

"I think it has the potential, finally, to reduce some of the transport using liquids that we do today," he said.

Continuous versus Intermittent

Continuous energy supply will be the world's first choice into the foreseeable future, Tinker said.

This is in contrast to what he calls "intermittent" energy – renewable sources like solar and wind – because they do not generate power under all conditions.

Intermittent energy has a role to play, especially in remote areas where distribution is difficult, but requires some combination of baseload backup generation or large scale, affordable, reliable storage, which is not easy to accomplish.

Thus, the world's primary electricity supply "will be dense, always-on energy, contrary to the popular preference for intermittent energy," he said. "We're talking about methane, hydrogen and uranium and thorium-nuclear."

Energy Demand

Some of Tinker's energy outlook varies from the mainstream.

He thinks nuclear energy will have a more meaningful role in the global future supply picture and predicted that China will surpass the United States in the number of operating nuclear reactors by the middle of this century. And India is likely to follow China.

Coal is a remarkable fuel – available, affordable and reliable. It is lifting China and other developing nations from poverty.

But, it has environmental challenges. Capture and sequestration of CO_2 emissions would make coal more atmospherically viable, but that is expensive, and the volumes are substantial. At the end of the coal section in "Switch," Tinker commented, "We probably could make coal clean. But we probably can't afford to."

His bottom-line message: The world of the future will need energy that is affordable, available, reliable and sustainable. But no form of energy is perfect and the availability and use of resources – from fossil to nuclear to renewable – vary by region.

Oil and Gas into the Future

Tinker has nothing but optimism for the oil and gas industry's ability to continue producing energy and power to meet the world's needs.

"Shale has had a gut-check, but that's all it is. It's a massive global resource," he noted.

He predicted that new technologies, like the technology that made the shale revolution possible, will greatly increase the industry's ability to tap into and recover hydrocarbon resources. And these same technologies will also reduce the environmental impact.

"I think we can go from 10 percent to 20 percent to maybe 50-percent recovery in the best parts of the shale basins using various yet-to-be-developed technologies," he said.

Over the course of 100 years, unexpected breakthroughs in energy sourcing could yet happen, Tinker agreed. A workable form of nuclear fusion, for instance, might provide a completely new source of power for society.

But it would take the world a considerable amount of time to absorb that type of breakthrough, he said. If 100

See **Technology**, page 15

Celebrating the Next 100 Years of AAPG

By BRIAN ERVIN, EXPLORER Managing Editor

Wallace E. Pratt. Charles Taylor. Sidney Powers. Michel T. Halbouty. Norman H. Foster.

Our Members aspire to their stature by keeping their names and legacies ever present through our annual awards and lectures, holding them up as examples of what can be achieved through the profession of petroleum geology.

They're not exactly household names outside of the oil and gas industry, but to initiates within AAPG, they are legends.

As such, they and others like them are the pillars upon which the modern age is supported. Our entire global civilization of the past century – from the fuel that makes worldwide travel and commerce convenient and possible, as well as the plastics and other materials that have given rise to the computer age and the Internet – all of this and much, much more has been entirely dependent upon the work and innovation of petroleum geologists like those who comprise the Membership of AAPG.

The quality of human life has been improved immeasurably over the past 100 years through technological advances that have only been possible because of petroleum geology.

And by all credible accounts, this will continue to be the case well into the next 100 years and beyond.

So, who will the Pratts and Halboutys of the next century be – those who will be responsible for the age of tomorrow? And what will the innovations and developments be that will power the human race into the next century?

In 2017, AAPG's centennial year, the EXPLORER will consider these questions in a new monthly suite of editorial features, not to look back at the century, but to look ahead at the next 100 years of AAPG, as well as the science and industry of petroleum geology.

The accompanying article is the first installment of our monthly "The Next 100 Years" section, which will explore how AAPG and its Members will shape the next century of human history by advancing the science of petroleum geology. We'll speak to present-day experts for their insights into what the future holds for the industry and the Association. We'll also include coverage of some of the technologies and services within the industry and their expected evolution in the decades to come.

Alaska's North Slope Heats Up

By HEATHER SAUCIER, EXPLORER Correspondent

The recent and apparently large oil discoveries on Alaska's North Slope by Caelus Energy Alaska and Armstrong Oil & Gas, Inc. and its partner Repsol have shown the world that giants may still exist in the 49th state. And, more might be waiting to be found.

Caelus estimates its 2016 find at nearly 6 billion barrels of oil in place. If its anticipated recovery rate of 30 to 40 percent is correct, its producible oil potential would be between 1.8 and 2.4 billion barrels. Armstrong is reporting contingent C1, C2 and C3 reserves of 497 million barrels (proven), 1.4 billion barrels (probable) and 3.8 billion (possible), respectively, in its discovery, which was announced in 2015.

Both point to new life on Alaska's North Slope, which hasn't seen a major discovery since the 1994 find of the Alpine field, expected to produce more than 750 million barrels of oil. If these new discoveries can be developed in a timely fashion, fears of the Trans-Alaska Pipeline System (TAPS) shutting down in two decades and an oil-dependent state going insolvent will likely ease.

Brought to light is a fairway stretching from the Colville River Delta to the west margin of Smith Bay, which is likely rich in conventional oil yet most efficiently extracted using unconventional technology. Sitting in stratigraphic traps that have remained mostly undetected until the advent of 3-D seismic, these hydrocarbons are now ripe for the picking.

Heterolithic sediment gravity flow deposits in the Torok Formation, exposed along an unnamed creek near the Sagavanirktok River about 85 miles south of Prudhoe Bay. These sandstones are roughly equivalent to the reservoir in the potentially giant discovery announced in Smith Bay, about 200 miles to the northwest. Images courtesy of David Houseknecht.

Race to Production

While Caelus has taken much of the media's spotlight after its October 2016 announcement, some believe Armstrong's find might be more viable at this point. Armstrong has drilled 16 wells, performed flow tests, and its discovered resources have been confirmed by third-party engineering firm DeGolyer and MacNaughton. Its discovery is closer to the existing infrastructure in the Alpine and Kuparuk River fields, making production more economically feasible, said David Houseknecht, AAPG Member and senior research geologist for the U.S. Geological Survey.

Caelus' discovery carries more uncertainty on all fronts, as only two wells have been drilled, neither has been flow tested, and the discovery is roughly 70-85 miles from infrastructure, he added.

"There is the potential for two giant oilfields," Houseknecht said. "At this point, the information released by Armstrong is more certain than Caelus', but both sets of information are very positive and both indicate that there is substantial potential in these two large discoveries."

In the eyes of Mark Myers, AAPG Member and former commissioner of Alaska's Department of Natural Resources, Armstrong's advantage is that its discovery – in the Colville River Delta – lies on land, unlike the Caelus find, which is located in shallow state waters in Smith Bay.

"It's easier to produce from onshore because you have no ice issues, and environmentally it's less difficult," Myers said.

However, in addition to the needed production infrastructure, given the estimated production rates of 120,000 barrels per day by Armstrong and up to 200,000 barrels per day by Caelus, these projects will require significantly more pipeline capacity than what currently exists to carry such volumes to Alaska's main oil artery, TAPS, Myers said.

Caelus has also reported that a financial climate of $65 a barrel would be needed to make its discovery cost effective.

Myers said he feels "confident in the geologic potential and the availability of appropriate technology to produce both plays" and remains optimistic about the North Slope's undeniable oil and gas potential.

"If proven to be commercial, just the potential resources that Caelus and Armstrong have announced alone exceed the USGS' current published assessment for mean technically recoverable conventional oil on all state lands on the North Slope. The scope of these recent discoveries shows that in spite of having produced more than 17 billion barrels of oil, the North Slope remains a very underexplored basin with huge undiscovered potential," Myers said.

"Many people have written off the possibility of finding this scale of discovery onshore or in state waters, but the North Slope is one of the most prolific basins in the world in terms of generating hydrocarbons. Technology is now at the point where even in low permeability conventional reservoirs many of these stratigraphic plays can now be successfully produced. It's a pretty exciting time."

Between Conventional and Unconventional

A roughly 100-mile long fairway – extending west from the Colville River Delta and spanning at least 40-50 miles wide – could contain numerous stratigraphic traps, such as those discovered by Armstrong and Caelus, Houseknecht said. These particular traps lie in the Nanushuk and Torok formations, which comprise delta and basin-floor fan deposits, respectively. This fairway includes the northeastern part of the National Petroleum Reserve – Alaska (NPRA) and nearshore state and federal waters.

Unlike the oil that migrated into Prudhoe Bay and the Kuparuk River Field from the south, Houseknecht believes oil also migrated into the Nanushuk and Torok from the north near the axis of the Barrow Arch. The same source rocks that fed the reservoirs of Prudhoe Bay and the Kuparuk River Field are present beneath the new discoveries, and are present in a series of downdip, offshore grabens north of the discoveries, Houseknecht explained.

The top of the Nanushuk at Armstrong's discovery is just 4,100 feet deep – meaning drilling costs may be relatively low and that the play could be drilled relatively quickly. "It may be more economically viable than a deeper reservoir," Houseknecht said.

While Caelus has not announced the depth of its discovery in the lower Torok, existing wells close to Smith Bay in NPRA suggest a depth of 5,500 to 6,500 feet.

Both reservoirs contain thick oil columns measuring 650 feet and more than 1,000 feet, reported by Armstrong and Caelus, respectively. Armstrong estimates up to 225 feet of net pay, while Caelus believes its net pay to be between 183 and 223 feet.

The Caelus discovery appears to have lighter oil with an API gravity of 40-45 degrees. Armstrong reports thicker oil with an API gravity of 30 degrees. The company also indicates an average reservoir porosity of 22 percent. Nearby wells in NPRA suggest Caelus' porosity to be in the upper teens.

In other words, in the Armstrong discovery the oil is thicker but the reservoir's porosity is higher, and high porosity usually translates into better productivity, Houseknecht said. With Caelus' discovery having lighter oil yet lower porosity, the two plays might be a wash in terms of productivity.

Comparisons aside, both discoveries have tapped into a hybrid type of play: conventional oil in a lower quality reservoir that often requires horizontal wells and hydraulic fracturing to maximize the efficiency of producing from these "transitional reservoirs."

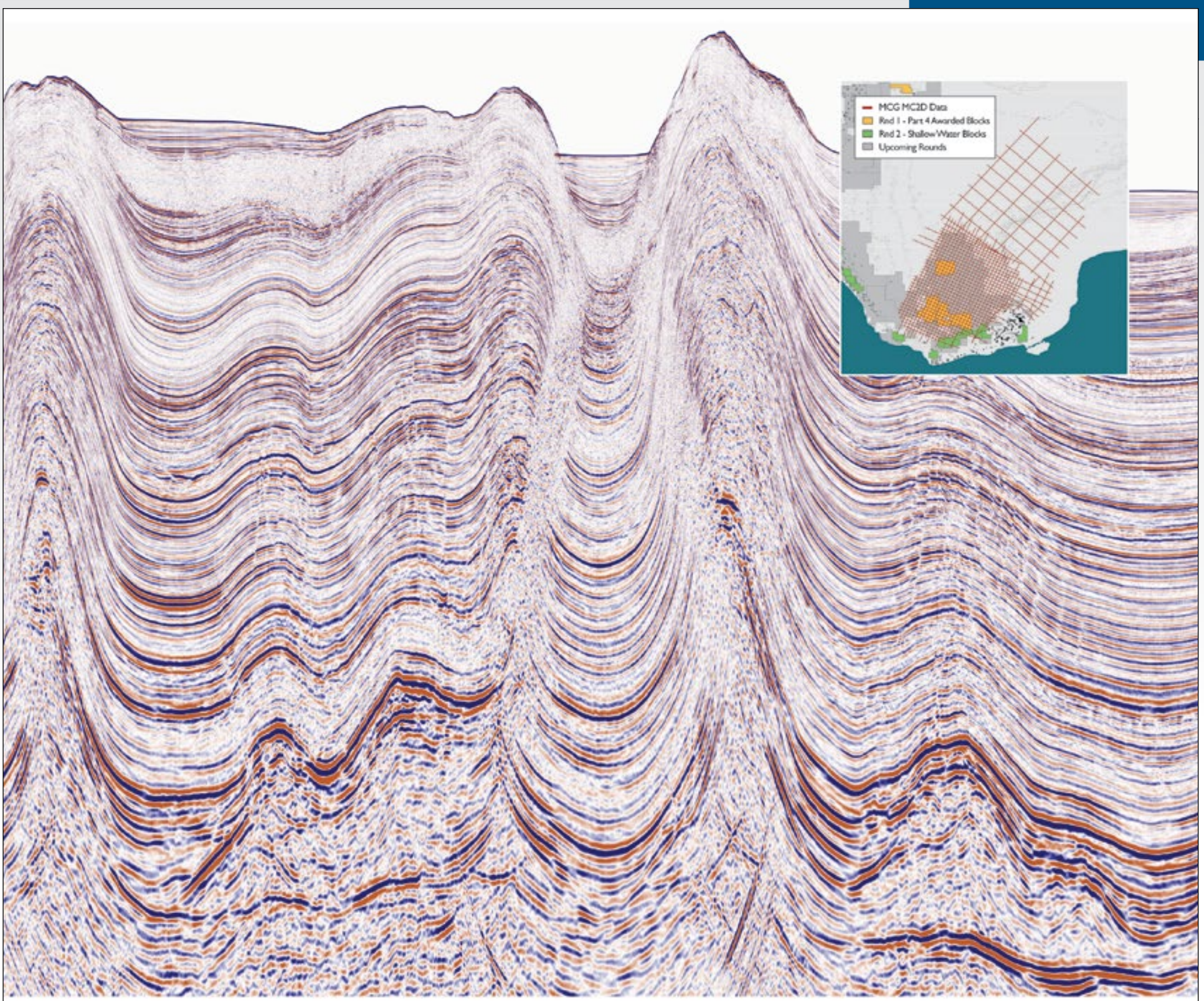
Hitting It Big Again

While Alaska's North Slope has been explored by geologists since 1901, with Prudhoe Bay being its largest discovery in 1968, the state is quickly becoming the "Comeback Kid." While most of the major operators have packed their bags, small to

See **Colville High**, page 14

Geologists examine near vertical, basin-floor fan deposits in the Gilead Sandstone along the Ivishak River, about 80 miles southeast of Prudhoe Bay.

Geologists measuring a section of the Upper Triassic Otuk Formation, a distal equivalent to the Shublik Formation, about 380 miles southwest of Prudhoe Bay. This is one of the westernmost exposures of Upper Triassic source rocks in Arctic Alaska, and may therefore provide information regarding source-rock potential beneath the Chukchi Shelf.



Colville High

from page 12

mid-sized companies are creeping along the north face of the Brooks Range with a fresh set of eyes, a new set of tools, a willingness to spend money and a savvy for subtle traps.

"These discoveries are likely to be very significant and likely to rank among top oilfields in Alaska and maybe even nationally," Houseknecht said. "The Armstrong discovery is so astounding because it literally sits on top of the Colville High, one of the very first areas explored in the state and one of the most heavily explored areas. It just goes to show that even in the intensely explored parts of Alaska there are still these opportunities lurking to discover giants."

The Armstrong discovery alone could boost throughput in TAPS by 30 percent or more, Armstrong has reported.

Myers describes the recent discoveries as the "start of an epic" play on the North Slope where the challenge is not in finding oil but in finding a good quality reservoir that is relatively shallow in terms of maximum depth of burial.

Another challenge sits on the political front. Wary of Alaska Gov. Bill Walker's decision to delay paying tax credits to exploration companies, Myers said it could have a negative impact on attracting new players to the field.

"I believe that it is in the state's interest to retain exploration credits because exploration is the riskiest part of the oil and gas business," he said. "Those are the incentives that brought Caelus and Armstrong to Alaska. I believe they are very, very important. I would recommend that the state should reevaluate the structure of its oil and gas taxes so that significant exploration credits are retained while credits and deductions for production from low risk and largely already capitalized existing proven fields are reduced."

Walker's office did not respond to requests for comment, but did issue a press release in 2016 noting, "My administration will continue to work with the industry to identify new development opportunities in Alaska's oil and gas sector, and provide appropriate investment incentives given our current fiscal climate."

The Long Road to Oil

On average, North Slope fields brought online to date have taken about eight years between discovery and sustained production, said Paul Decker, AAPG Member and manager of Resource Evaluation in Alaska's Division of Oil and Gas. Some have taken much longer than that.

"There is a full process that unfolds between initial discovery and project startup: additional exploration and delineation drilling, flow testing, facilities and infrastructure engineering and design, state and federal environmental impact analyses, developmental permitting, commercial negotiations to secure capital funding, and alignment among mineral, surface and working interest owners, followed by project sanction and construction," Decker said.

While Armstrong anticipates production beginning in 2021, only time will tell. In the meantime, "The Last Frontier" state will likely continue to live up to its name.

Threshold

from page 8

- Senegal
  Kosmos Energy Ltd, Cayar Offshore Profond Block, Teranga-1 well, 5 Tcf of gas plus some condensate
- Angola
  Cobalt International Energy LLC, Offshore Block 20, Kwanza Basin, Zalophus No. 1 well, 2 Tcf gas plus condensate
- Myanmar
  Posco-Daewoo/Woodside, Offshore AD-7 Block Rakhine Basin, Thalin-1A well, 1.5 Tcf gas
- Angola
  Cobalt International Energy LLC, Offshore Block 20, Golfinho No. 1 well, 200 million barrels oil, 290 billion cubic feet of gas
- Russia
  Gazprom, Northeast Sakhalin Sub-basin, Lunskoye Yuzhnoye discovery well, 1.2 Tcf gas plus condensate
- Gulf of Mexico
  Chevron Corp., Keathley Canyon, Gibson prospect exploration well, 195 billion barrels of oil equivalent plus condensate

Lately, conventional wisdom has held that the future of exploration belongs to the national oil companies, or NOCs. That's especially true when they are tapping into resource abundance in their own countries.

But look at this year's top international discoveries list, as well as the best North American wells total, and you'll find a significant number of U.S. independents among the operators.

Cobalt International has headquarters in Houston, Kosmos Energy in Dallas. Caelus Energy is based in Dallas and Anchorage.

"The U.S. independents are still out there taking risks," Stark said. "There are high risks out there in places that have the best prospects for discoveries."

Stark doesn't see the international exploration picture getting better until more money comes into risk drilling and that likely depends on the willingness of OPEC and Russia to heed production quotas.

"We'll just have to see if the recent OPEC announcement reestablishes their role in the market," he said.

Uncertain geopolitics, the threat of terrorism, constrained economics and industry malaise have all made exploration a tough game to play, on a very wild and challenging international frontier.

"Until you get back to a healthier oil price," Stark said, "a lot of companies are reluctant to push money out into the frontier areas of the world."

Exploring a fumarole field in Iceland, the leader in geothermal power.

Technology
from page 10

new coal plants are built now, they wouldn't be torn down just because a new form of power appeared, Tinker noted.

"If nuclear fusion were to prove possible, safe and scalable tomorrow, it would take decades for that to be deployed globally," he said.

Tinker does expect an advance in the world's understanding of its own energy needs, uses and potential efficiencies.

"So in 100 years out, I see a very different world. The biggest difference will be our ability to understand the data and the digits," he said.

The future should give us a better grasp of not only how we use energy, but how we can and should use it more efficiently.

"In that world, that's juxtaposed against population growth and industrialization, I can see actual energy use declining," Tinker said.

"With wide efforts on all fronts, there will be an educated populace and we won't have nearly 3 billion people living in energy poverty," he added.

The "Switch" education project and documentary are still reaching people around the globe, Tinker noted.

"'Switch' continues to roll. Everywhere I go in the world, people tell me their professors are showing it and they're talking about it in class," he said.

Combating Energy Poverty

What has Tinker's attention now are all those people and nations living in energy poverty.

Tinker wants to engage future leaders to help solve global energy poverty and has launched the Switch Energy Corps, which employs graduate students as "energy missionaries."

"The way we're going about that is to look at places in the world that have no electricity, initially in Latin America and then moving into Asia and Africa," he said.

Experiencing severe poverty and doing something positive to solve the problem is much more powerful than the "protest and criticize" movements made popular on some college campuses.

"Students are lining up!" he said.

Want to know how all that will play out over the next 100 years?

Wait 100 years and see.

Tinker holds no illusions about the difficulty of predicting a century ahead.

"My great-grandchildren will have belly laughs about how wrong we were," he said. "But hopefully they will know we were giving it our absolute – and honest – best."

Wells
from page 6

three water well locations. Paul Bauman of Advisian WorleyParsons, in Calgary, oversaw the project and students from the University of Calgary and several volunteer geophysicists from the firm provided additional fieldwork. Additionally, 28 students from IsraAID's water, sanitation and hygiene program, which provides training in water-resource management and technology, participated in the geophysical fieldwork. These wells produced at a rate that will supply approximately 140,000 people per day with the recommended amount of water. Additional targets will be drilled in an extension of the program.

Industry Perception

Echoing the organization's mission statement, Merrill said it is important that the projects are learning experiences for students. He hopes it will stoke an interest and show the possibilities of careers in the geosciences.

"The goal is not only to provide funding to projects that will benefit communities in need, where applying geoscience and information is critical to improving poor conditions, but also to encourage students to pursue the broad range of geoscience careers and to strengthen the global geoscience community through beneficial multidisciplinary partnerships and cooperation with other organizations," he said.

Personally, for Merrill, he got involved because he liked the concept of giving, improving, repairing – concepts embodied in the forerunners to GWB, Doctors Without Borders and Engineers Without Borders.

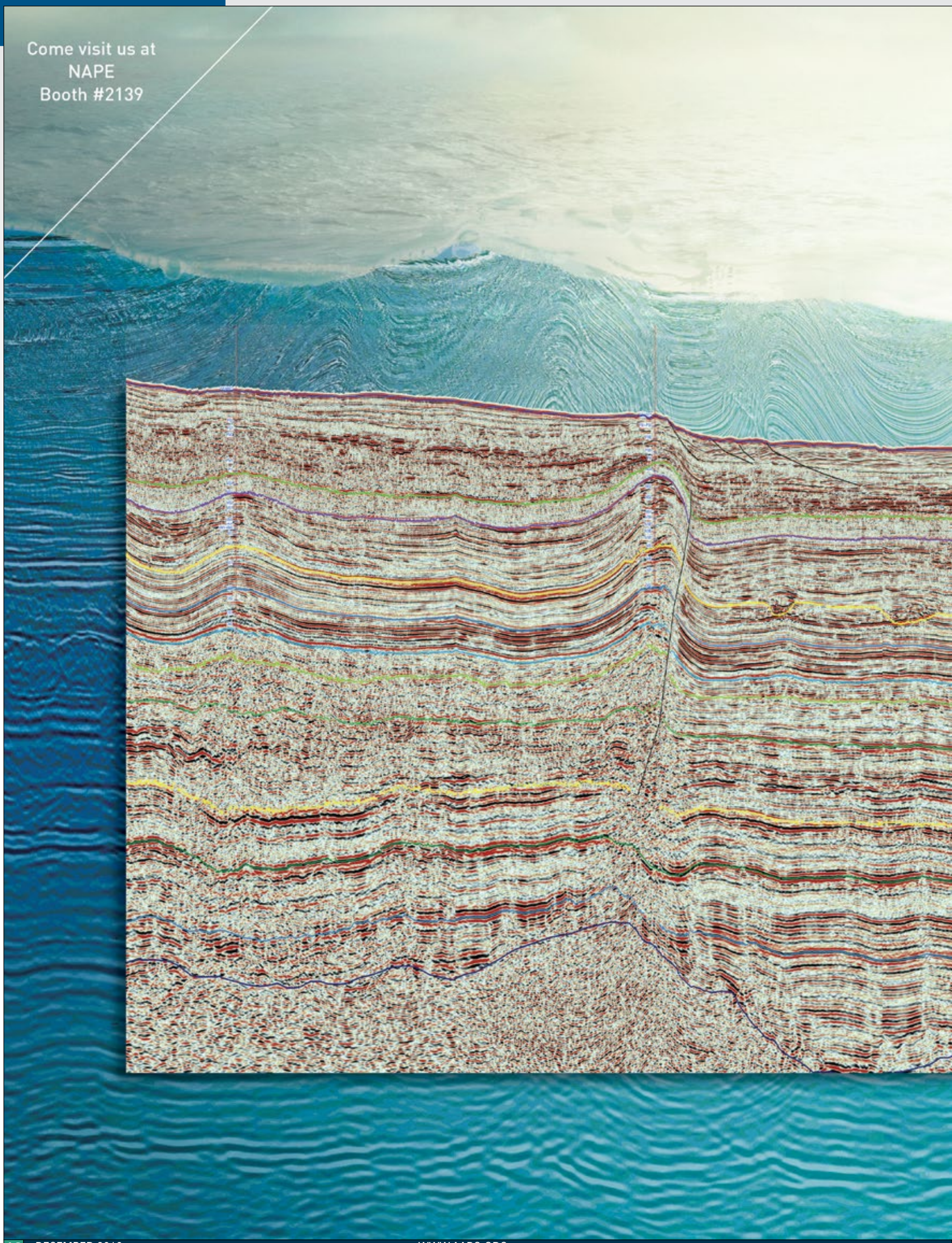
The parallels, as one might imagine, mean there might be impediments to the work – often political – as was the case in those refugee camps. Merrill said he recalls only one project, in Afghanistan, that was deemed too politically volatile. Most of the time, though, before GWB begins its work, negotiations between scientists and national politicians have already taken place.

Asked whether this is a tough sell for these local geologists, Merrill said that it's more a matter of convincing the government official that there are solutions out there that can make their countries better.

"They all, it seems, have the same questions: 'What's the problem, what's being done and how's it going to help us?'"

There is another dynamic at play, something Merrill said he hadn't thought much about it, and that is the perception of those in the industry. He knows of the good work – he orchestrates some of it – being done by geoscientists, the noble work around the globe.

"Yes, now that you mention it, I do want people to know what the community is capable of doing."



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.

Deeper Waters

How science and technology pushed exploration to greater depths

By PAUL WEIMER

Today, there are 31 sedimentary basins worldwide that produce or have economic discoveries in deepwater, in terms of both modern water depths and reservoir type.

Exploration wells have now been drilled in water depths up to 11,155 feet (Pelotas Basin, Uruguay), and the deepest offshore production at present is 9,656 feet (northern Gulf of Mexico).

We all know successful deepwater production has profound economic impact. Sometimes, however, it is difficult to grasp how profound the economic impacts are. To get an idea, consider that the total gross income collected by the U.S. federal government from offshore oil and gas resources averaged $8 billion per year from 2005 to 2014, according to the Congressional Budget Office. That's compared to $3 billion from onshore resources for the same period.

How did our industry move into deepwater provinces in the past seven decades?

What were the drivers behind this multibillion-dollar investment of resources?

The global story of deepwater petroleum exploration is not one that has a great deal of intrigue, like the Teapot Dome scandal or other early (mis)adventures in petroleum geology. Likewise, our story never had a master plan. Rather, this is a tale of gradual evolution – one in which the role of technology and science are inextricably linked to the economic need to discover new resources for an expanding global population.

New Technology and Science

The desire to explore in greater water depths required new seismic technology to accurately image the subsurface, new scientific disciplines to analyze the geology and geophysics, and new technology to drill and develop resources.

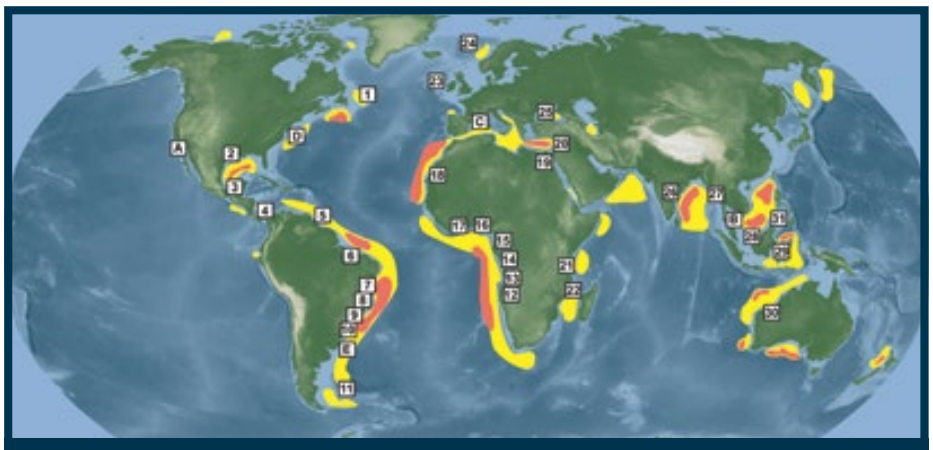
For example, with the development of common depth point seismic and digital recording in the mid-1960s, vast amounts of 2-D marine seismic information began to be collected. The continued improvement in acquisition, in terms of streamer design, allowed for improved subsurface imaging. This new information, in turn, presented new kinds of geology that had not been imaged before. The fields of seismic and sequence stratigraphy evolved from evaluation of these data, heavily influenced by early exploration of the North Sea and other basins. Meanwhile, the recognition of geophysical "bright spots" on seismic reflection data was critical to exploration success in deepwater, and became one of the technical drivers in moving into progressively deeper-water frontier provinces for drilling.

Finally, the development of innovative drilling technology and production techniques were also essential to making deepwater economical.

Defining Terms

Like many geologic disciplines, there is a tremendous amount of jargon for deepwater. So let's define two terms. First, let's use the term "turbidite" to refer informally to any sedimentary gravity flow deposit regardless of water depth for deposition. Second, "deepwater" has two definitions. The geologic definition refers to water depths where sediment gravity flows tend to dominate, which generally means greater than 300 meters (although lakes are the exception). The engineering definition considers deepwater to be where fixed platforms can no longer be used for development. Instead, some sort of floating development structure is required; typically this is greater than 1,500-feet water depth.

I will use the second definition throughout this article.



Global map of all basins in greater than 1,500 feet water depth with fields or economic discoveries: 1. Eastern Canada 2. Northern Gulf of Mexico 3. Southern Gulf of Mexico 4. Colombia 5. Guyana 6. Potiguar 7. Sergipe Alagoas 8. Espírito Santo 9. Campos 10. Santos 11. North Falklands 12. Angola 13. Cabinda 14. Gabon 15. Equatorial Guinea 16. Nigeria 17. Ghana-Core D'Ivoire 18. Senegal-Mauritania 19. Nile 20. Levant 21. Tanzania 22. Rovuma 23. Shetlands 24. Central Norwegian shelf 25. Black Sea (Romania) 26. Krishna-Godavari 27. Myanmar 28. Brunei-Sabah 29. Mahakam 30. NW shelf- OZ (three sub-basins) 31. West Philippine Sea. Additional sites for drilling records (figure 5) are shown: A=Santa Barbara (1970) B=Andaman Sea (1976) C=Gulf of Lions (1982) D=Baltimore Canyon (1983-1984) E=Pelotas Basin Uruguay (2016). Areas with good exploration potential are shown in yellow (deepwater 1,500-6,000 feet) and orange (ultra deepwater greater than 6,000 feet).

WEIMER

Paul Weimer is an AAPG past president and holds the Bruce D. Benson Endowed Chair in the Department of Geological Sciences at the University of Colorado, and serves as the director of the Energy and Minerals Applied Research Center. He began research on deepwater deposits in 1978 and has continued to prod the broad topic for many years since then. He is also the co-chair of the 100th AAPG Anniversary Committee.

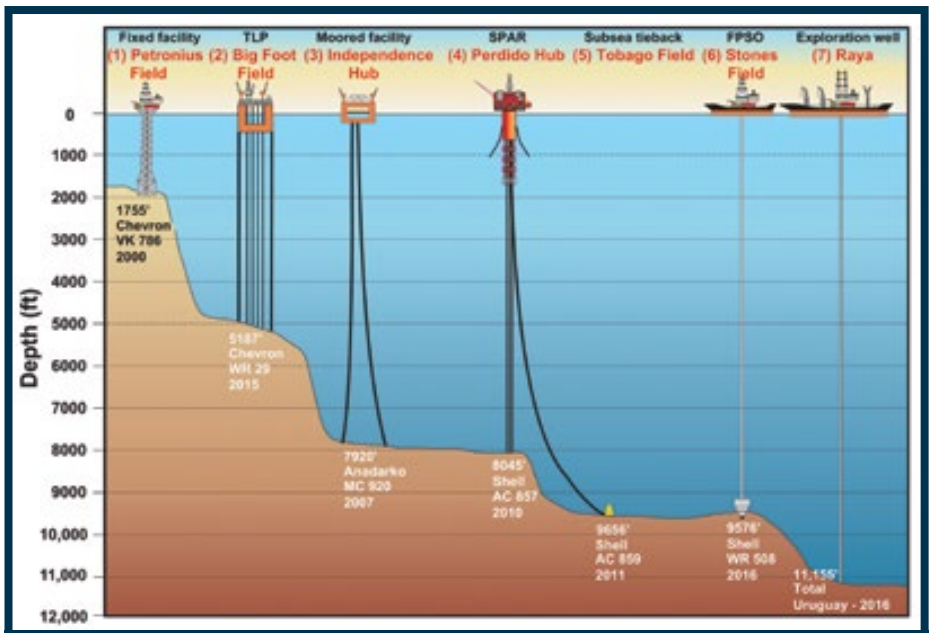
Pioneers in Sedimentology

The important first step in deepwater exploration was the recognition that turbidite reservoirs exist. Ironically, some of the first oil fields discovered in the world were in turbidite reservoirs. Some of the reservoirs discovered in western Pennsylvania were likely in Devonian turbidites. Many of the giant fields in California discovered in the late 1890s and early 20th century had turbidite reservoirs. Examples include the southern San Joaquin, Los Angeles and Ventura basins. In 1930, Royal Dutch Shell discovered the supergiant Poza Rica field in onshore Mexico. The field produces from primarily Lower Cretaceous base-of-slope carbonate debrites and some turbidites. The Poza Rica field has the largest stratigraphic trap in conventional deepwater deposits.

However, in all of these examples, it was not until the late 1940s and '50s that the correct depositional setting of the reservoirs was recognized. Select companies began to realize that many of their fields in fact had deepwater turbidite reservoirs.

Manley Natland did pioneering work in the early 1930s in several southern California basins. From modern marine studies, he recognized that the deepwater benthic foraminifers living in offshore basins in the Los Angeles area were also found in the shales encasing the coarser-grained sands and conglomerates in the nearby Plio-Pleistocene reservoirs and outcrops of the Ventura basin. Natland was so intrigued by these processes that he altered the bottom of his swimming pool to create ridges to simulate the effects of irregular bathymetry of the Neogene Los Angeles Basin, and then poured sand and mud into the pool to generate turbidity currents. (His son Martin confirmed this story in July.)

European sedimentologists Phillip Kuenen, Carlo Migliorini and their students also did pioneering deepwater research at the same general time. Their seminal work in outcrops and flume tanks began to gain acceptance in the late 1940s and '50s. By the 1960s, critical outcrop studies by Arnold Bouma, Emiliano Mutti and Franco Ricci-Lucci led to the development of facies classifications that were essential for the correct depositional interpretation of deepwater reservoirs. Later work in the 1970s by several workers continued to advance the understanding of depositional processes and facies association.



Schematic diagram showing the world-record water depths for exploration and development facilities, and years of first usage. TLP=Tension Leg Platform; FPSO= Floating Production Storage Offloading.

Three Key Basins

Initially, three areas were key to the successful transition of exploration into deepwater: the North Sea, the northern Gulf of Mexico and Brazil.

The reservoirs discovered in these basins were essential for the recognition that deepwater reservoirs could produce at high and sustained rates, which were critical to making these plays economic.

The exploration story for deepwater sandstones began in earnest with the early oil discoveries in the North Sea basin. Although the modern water depths do not exceed 400 meters, the discovery of turbidite reservoirs in a number of fields was an essential step in the understanding of deepwater reservoir systems, impacting future deepwater exploration. After the 1958 United Nations treaty divided the North Sea into economic zones by country, exploration gradually moved from onshore into the shelf region. Marine seismic acquisition grew throughout the 1960s.

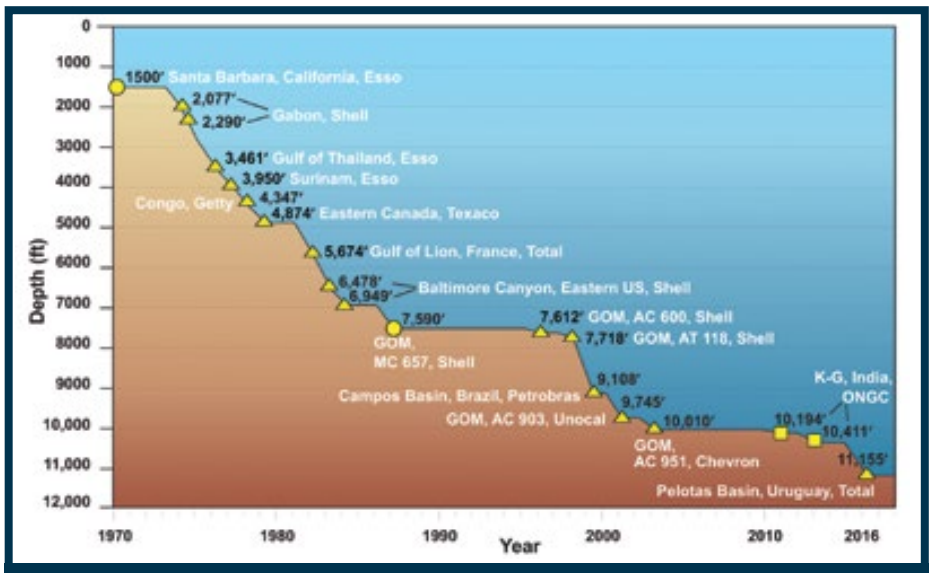
Ironically, two of the first fields discovered in the Central Graben of the North Sea were in turbidite reservoirs. First, Ekofisk was discovered in 1969, where the main reservoirs are lower Paleocene resedimented chalk turbidites. Then, the following year, the Forties field was discovered in upper Paleocene sandstones.

There was considerable internal discussion at BP, the operator, about the depositional origin of the Forties reservoir sandstones – were they shallow marine or deep marine?

After a few years, the data collected for the field began to point toward a major delta-fed, base-of- slope deposit. Specifically, the reservoir was encased

Continued on next page

January Manley Natland (with camera) filming the generation of turbidites in a flume at Union Oil Research Laboratory, Brea, Calif., January 1965. Photo courtesy of Martin Natland.



Record water depths for drilling by the end of each year. Location of wells and operator are indicated. GOM=Gulf of Mexico, AC=Alaminos Canyon, AT=Atwater Valley, MC=Mississippi Canyon, K-G=Krishna-Godivari. Triangles=dry holes, circles=producing field, square=discovery. Location of basin shown in figure 1.

Continued from previous page

between deeper water microfaunal and palynological assemblages, distinct clinoforms prograded across the top of the deeper water reservoir systems, and associated sedimentologic studies were pointing toward sedimentary gravity flows. With the discovery of Forties, a number of other deepwater reservoirs were quickly discovered associated with the Paleocene systems as step-out from Forties; these included such fields as Maureen, Andrew, Montrose, Frigg and Nelson.

Additional turbidite discoveries were made in the syn- and post-rift Jurassic and Early Cretaceous strata: Magnus, the Brae complex, Britannia and Claymore fields. About 25 percent of the historical production in the U.K. North Sea has come from turbidite reservoirs.

GOM and Bright-spot Technology

In the northern Gulf of Mexico, exploration after World War II continued to move into deeper water depths across the shelf. Offshore Louisiana in 1947, Kerr McGee drilled the first well that could not be seen from land. The progressive movement of exploration into deeper water depths on the shelf continued for the next 30 years. The first significant discovery off the shelf was the 1975 Cognac Field in 1,030 feet of water; the reservoirs were primarily upper slope and deltaic sands.

The major technical driver in moving exploration into the upper slope and deeper water was the use of bright-spot technology, initially developed by Mike Forrest and colleagues at Shell, and independently developed at Mobil. This approach was especially effective in discovering fields both on the shelf as well as in deeper water. The larger fields were discovered beginning in the mid-1980s to early '90s and include Auger, Mensa, Mars, Ram Powell and Ursa. Today, the northern deepwater Gulf of Mexico has 226 fields and discoveries; all but four of them are in turbidite reservoirs. Yearly production in 2014 was 416 million barrels of oil and 688 billion cubic feet of gas.

The movement into deepwater was gradual at first, limited by drilling technology. Drill ships became necessary to drill in much greater water depths. Specialized ships were initially developed for the Deep Sea Drilling Project Scientific Drilling Program in the 1960s. By the mid 1970s, several drill ships were built and used by industry.

Initial record water depths for drilling were in eight basins globally between 1970 to 1984. However, from 1987-2011, all record water depths were in the northern Gulf of Mexico.

An important trend has been the abrupt increases in the water depths for drilling during short time periods: 2,000 to 5,000 feet (1975-79), 5,000 to 7,000 (1981-84), 7,600 to 9,000 (1998-99), and 9,000 to 10,000 (2000-03).

In addition to drilling, new development technology was necessary to develop these large fields. Subsea tiebacks, now a common production technology, got their start in the North Sea. Likewise, underwater pipelines, tension leg platforms, floating platforms and floating production storage offloading units have been essential technologies.

Brazil and Petrobas

Brazil is also a very important part of this deepwater story. Petrobras drilled its first onshore discovery in 1954; by 1968, the first offshore well was drilled in 10 meters of water in the Espirito Santo Basin, testing a structure that had alternative interpretations of a salt diapir or an igneous intrusion. The well was unsuccessful but proved the presence of evaporites in the continental platform, creating expectations of a new frontier with structures and plays similar to the Gulf of Mexico. In 1968, the Guaricema Field in the Sergipe-Alagoas Basin was discovered in a water depth of 20 meters; similar to some of the North Sea discoveries, there was considerable internal discussion as to the environment deposition of the reservoir. Bill Fisher, working as a consultant, suggested that the reservoirs were, in fact, deepwater sands; this observation led to a change in exploration paradigm for potential reservoirs.

In 1974, Petrobras discovered the first oil field in the Campos Basin in Albian carbonates, and in less than a year the exploration focus moved to siliciclastic reservoirs in shallow waters, which were interpreted as turbidite sands deposited from Late Cretaceous to Mid-Tertiary. By 1982, Petrobras drilled successfully in the upper slope in the Campos Basin in about 400 meters of water.

The next big jump happened in 1984 when drill ships were brought to the Campos Basin and the Albacora (1,400 feet) and Marlim fields (2,800 feet) were discovered. These two major discoveries opened an entirely new deepwater frontier in the south Atlantic.

More than 40 fields in the deepwater of offshore Brazil are in Lower Cretaceous to lower Miocene turbidite-related reservoirs. In 2015, the daily production in the Campos Basin from these deep-water sand reservoirs was nearly 1 million BOE/day.

Continued Evolution in Seismic Data

Another major jump for deepwater exploration happened during the early to mid-1990s, when marine 3-D seismic became routinely available for regional evaluations, and countries began to allow deepwater exploration in areas previously inaccessible.

For example, the 3-D seismic data collected along the West African margin led to major discoveries in Angola, Congo, Gabon, Equatorial Guinea and Nigeria. These new seismic data also stimulated companies to reassess their concepts of how deepwater sedimentary systems operate. The depositional models that had been developed with 2-D seismic data needed modification where the 3-D data could very accurately image the depositional elements. Meanwhile, the need for 3-D seismic to image the geology below thick allochthonous salt led to cost-effective development of pre-stack depth migrated data. In addition, companies began to reassess deepwater outcrops to help construct accurate reservoir models. Flume studies also began to increase in complexity as companies tried to replicate the interpreted processes of the gravity flows. 4-D seismic (repeat 3-D) also became an essential tool for imaging the movement of fluids during field development in many productive basins.

Continental and Shallow Marine Reservoirs

Although most deepwater fields and discoveries have turbidite sand reservoirs, a number of reservoirs deposited in shallow marine to continental environments have been discovered in modern deepwater (greater than 1,500 feet). All of these reservoirs represent deposition in the earliest portion of these margins' tectonic development. The most notable are the pre-salt Lower Cretaceous reservoirs in the Santos and Campos basins in Brazil and their mirror image basins offshore Angola (Kwanza and Namibe). Reservoirs are mainly microbial carbonates, coquinas and cherts deposited in rift lakes. Those fields already produce more than 1 million BOPD in the Santos and Campos basins. Other discoveries include: Upper Jurassic eolian reservoirs in the northern deep Gulf of Mexico; Upper Jurassic fluvial-estuarine reservoirs in the Bay du Nord, offshore eastern Canada; Lower Cretaceous lacustrine deposits in the northern Falkland- Malvinas Basin; Lower Cretaceous shallow to marginal marine reservoirs in offshore Senegal; middle Miocene carbonate buildups in offshore Egypt; and upper Miocene carbonate reservoirs west of the Philippines.

The Future?

At this point we must ask: what is next for deepwater exploration and development? The recent price downturn has had a significant global impact on the economics of deepwater. Many deepwater plays are not profitable in the current low-cost environment due to high capital and operating costs. Clearly, an increase in oil price and/or a decrease in operating expenses are essential for deepwater exploration and production to remain profitable in the future.

Acknowledgments

To insure historical accuracy, I have consulted recently with several colleagues for reconfirmation of facts and more details: Greg Blake, Mike Bowman, Don Clarke, William Fisher, Joan Flinch, Mike Forrest, Bob Frykland, Stephen Graham, Paulo Guimaraes, Will Gutterman, Alfredo Guzman, Andrew Hurst, Laurie Lamar, Todd Lapinski, Dorie McGuinness, Bud McGuire, Bob Mitchum, Webster Mohriak, Martin Natland, Henry Pettingill, David St. Hubbins, Art Saller, Craig Shipp, Matthew Silverman, Derek Smalls, Pete Stark, Mike Sweet, Mario Suarez, Gabor Tari, Clint Tippett, Nigel Tufnel and M. S. Wacker.

To all of them, I extend my sincerest thanks.

(From left) Emiliano Mutti, Arnold Bouma and Franco Ricci-Lucchi in the Apennine Mountains, Italy, September 1988. Photo by Martin Link.

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.

Deciphering Seismic Amplitude Language

By LUIS VERNENGO, EDUARDO TRINCHERO and SATINDER CHOPRA

Interpretation of seismic amplitude anomalies could be a direct solution to finding hydrocarbons, or defining lithology, but is usually a tricky problem. Isolated seismic amplitude values higher than the average background amplitude levels are termed as "seismic amplitude anomalies."


CHOPRA

It is quite common to see confusion prevail in G&G study groups when discussion is going on about seismic amplitudes anomalies.

The anomalous behavior of seismic amplitudes may arise due to some peculiarities in the subsurface, which may be due to a number of reasons, including the following:

- Clean wet sands with high porosity and thickness greater than the tuning thickness at the target level may exhibit low acoustic impedance, and thus show up as an amplitude anomaly.
- Thin layers of salt, volcanics and carbonates, which are usually associated with high interval velocities when sandwiched between sand or shale layers, may exhibit strong reflections in otherwise continuous reflection campaigns. Similarly, coal or soft shales sandwiched in sands may show up as high amplitude reflections or anomalies.
- Thin geologic formations with varying thicknesses may give rise to amplitude variations due to tuning phenomenon. There may be other situations such as absence of reservoir sands updip or downdip causing seismic amplitude variations.
- Seismic amplitude anomalies may be generated as artifacts during processing of seismic data if data are not processed optimally, e.g. concave or convex geologic bed shapes in the subsurface may give rise to focusing or defocusing effects respectively, and in turn produce stronger or weaker reflections. Similarly, when using neural networks for reservoir property determination, artificial seismic anomalies may be generated as artifacts as a result of overtraining data.
- Low-impedance gas sands sandwiched between shale layers can give rise to strong amplitude anomalies. However, as a low-gas saturation may exhibit a similar seismic amplitude response as a high gas-saturation, a strong seismic amplitude anomaly may be associated with "fizz gas," instead of a hydrocarbon-bearing sand.

Seismic amplitude anomalies have been found in sand formations of all geologic ages ranging from the older (Cretaceous, Triassic) to the younger (Tertiary). But besides compaction, depth of burial, porosity, lithological composition and the presence of fluids (gas, oil) are other factors that may influence the impedance contrast shown by an anomaly. It is difficult to distinguish oil from gas in a direct hydrocarbon detection workflow, as oil may contain dissolved gas. Also, low-gravity oil may show less of an impedance contrast than high GOR (gas/oil ratio) light oil.

By making use of the available dipole sonic and density logs from the area under investigation, the seismic response can be forward-modeled. The elastic gathers so generated can help understand what kind of response to expect from the target reservoir levels, and if a seismic anomaly would be associated with gas or oil.

It is important to understand the geologic setting of the target formations and their depositional environment, so the interpreter has a feel for the kind of formation consolidation to expect. This will have a bearing on the type of amplitude variation with offset (AVO) anomaly to expect. For example, consolidated sands may exhibit a class 1 anomaly, a moderately consolidated sand, a class 2 and an unconsolidated sand a class 3 anomaly. A class 4 anomaly is generally seen for lower-impedance sands below high-impedance shale or carbonate rocks.

These anomalous class variations are examined on prestack seismic data, i.e. gathers, which are stacked to generate seismic traces. Seismic gathers allow investigation of the amplitudes as a function of offset or angle. Near-, mid- and far-offset or angle volumes are created to study the seismic amplitude anomalies, and if they show an amplitude response as seen on the modeled response, confidence is gained in the analysis.

For reducing uncertainty in the seismic anomaly interpretation, the seismic data should be put through true-amplitude processing, i.e., seismic amplitudes should be preserved at each step in the processing sequence. The phase of the seismic data being interpreted should be understood well so that impedance

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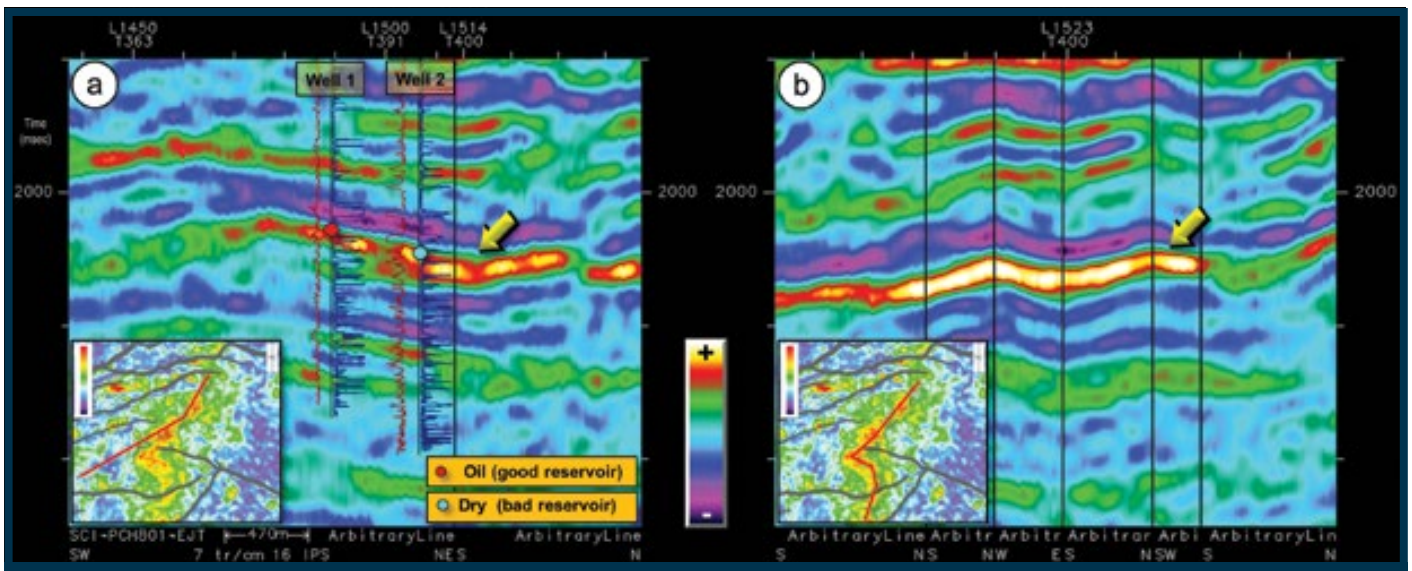

Figure 1: Arbitrary profiles passing through the relative P-impedance volume through wells 1 and 2 as shown in the inset. The two overlaid curves are the spontaneous potential in red and the resistivity in blue.


VERNENGO

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.


TRINCHERO

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.

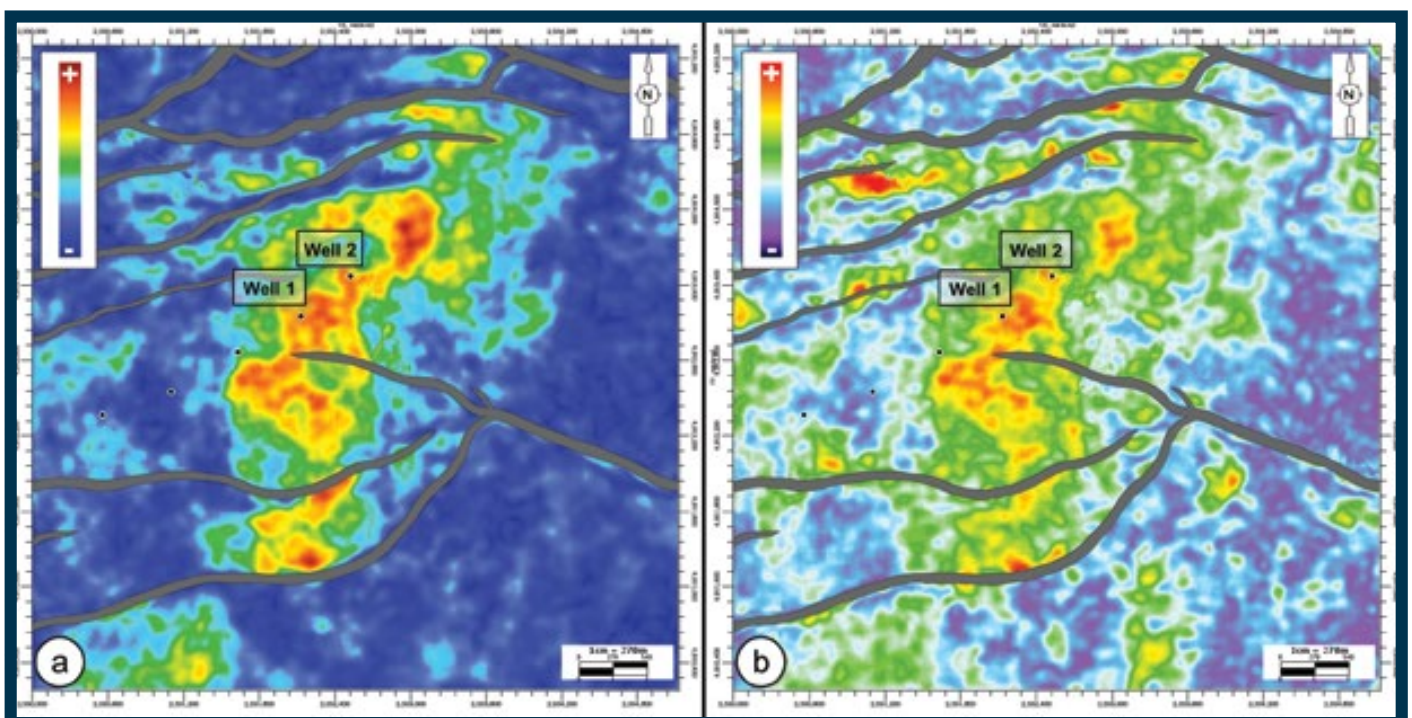

Figure 2: Equivalent horizon slices from (a) seismic amplitude volume, and (b) relative P-impedance volume. The two overlaid curves are the spontaneous potential in red and the resistivity in blue.

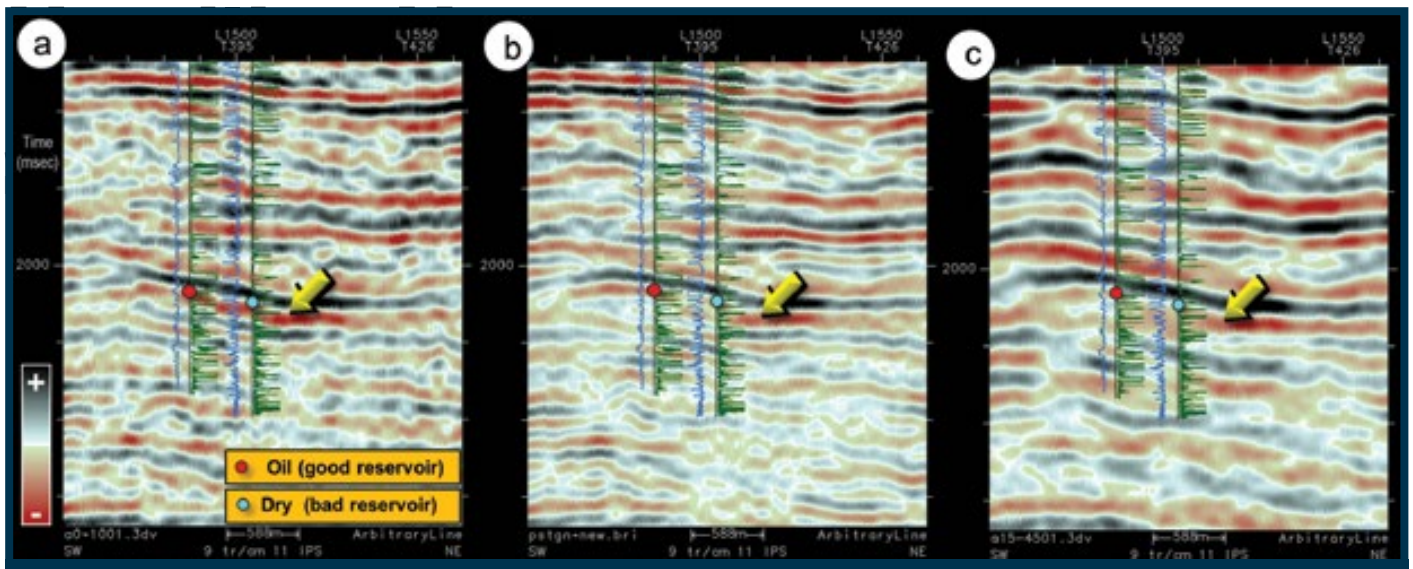

Figure 3: An arbitrary profile similar to the one shown in figure 1, but passing through the (a) near-, (b) mid-, and (c) far-offset seismic volumes. As indicated with the yellow arrows, even though the reservoir seems to be at the same geological level, no AVO signature is seen. The overlaid curves are the spontaneous potential in light blue, and resistivity in green.

Continued from previous page

contrasts can be interpreted properly. Examining the seismic phase and polarity of the data being interpreted, and keeping it consistent for all data under investigation can be helpful in confidently carrying out amplitude anomaly analysis.

The strength of an anomaly may be measured by normalizing it to the background amplitude levels. Also, comparing the strength of hydrocarbon-charged anomalies in an area with the strength of the other anomalies associated with lateral geologic variations can be very helpful.

Tuning prevents meaningful interpretation of amplitudes in terms of lateral property changes. Should the data have tuning problems, the frequency content of the seismic data can be enhanced in an amplitude-friendly way and the data can be detuned.

There may not be any one unique way to carry out a foolproof analysis of seismic amplitude anomalies. Developing a consistent workflow for interpreting seismic amplitude anomalies and de-risking them may not be straightforward, but sustained efforts at examining the amplitude strength and the character of its lateral terminations in the light of what has been mentioned earlier could be helpful. This can be important, as the prospect evaluation may not be just the prediction of the presence of the reservoirs and their areal distribution, but also the prediction of possible hydrocarbons within the reservoirs.

Examples

In spite of taking adequate precautions and following a logical workflow, we may encounter exceptions that demand answers. We illustrate this by citing some examples below from the San Jorge Basin in Argentina.

In figure 1a we show an arbitrary profile through the relative P-impedance volume generated using colored inversion passing through two wells, 1 and 2, as shown in the inset.

The higher impedance values indicated with the yellow arrows do not necessarily imply productive reservoirs. In fact, the high impedance corresponds to the tuffaceous sandstone at that level, and the variation in impedance there is reflective of lithology change. Another arbitrary profile through the same impedance volume, but tracked along the signature of the impedance anomaly is shown in figure 1b. The seal rock is mainly tuff but has sandstone component present as well.

In figure 2 we show the horizon slices from the seismic (figure 2a) and the relative P-impedance volumes (figure 2b) for the same data shown in figure 1. The anomaly seen on the seismic amplitude in red and yellow is seen better defined on the impedance. Well 1 came out oil bearing and well 2 was tested dry, perhaps being too close to the edge of the anomaly. The other wells seen on the displays did not encounter the reservoir.

Figure 3 shows the same arbitrary profile as shown in figure 1, but now from the (a) near-offset, (b) middle-offset and (c) far-offset seismic volumes. The yellow arrows indicate the amplitude response of the anomaly on these displays. We notice that even though we see an anomalous response for these amplitudes in figure 2a, there is no AVO effect seen here for the oil reservoir encountered in well 1, being more prominent for a gas reservoir.

An arbitrary profile passing through two wells from a seismic volume acquired in a structurally complex (fold and thrust belt setting) area falling to the west of the data shown in figure 1 to 3 is shown in figure 4. The well to the left encountered a gas reservoir, but the well to the right came out dry. The geological level and strength of the amplitudes seem to be similar for both wells. The black peaks at the location of the two wells indicated with cyan arrows in figure 4 seem to be related to the same reservoir behavior, but while the first well to the left was gas bearing, the well to the right and drilled after the first one came out dry, with no reservoir but a hard rock instead. Post-mortem analysis indicated a class 4 AVO anomaly for the target level to the left, with no AVO anomaly at the target level to the right.

In figure 5 we show an equivalent arbitrary profile to the one shown in figure 4, but passing through the reflection strength volume instead of the seismic amplitude data. The geological level for the reservoir seems to be associated with similar reflection strength amplitudes, but the well to the left encountered a gas reservoir at that level, and the one to the right came out dry (bad reservoir).

Conclusions

The recognition of seismic anomalies and their interpretation requires a systematic and consistent workflow or a series of steps. Beginning with gaining knowledge about the general geology of the area and the depositional environment of the target formations, one could go on to making use of the required well data and generating modeled elastic gather response at appropriate frequencies, comparing with processed seismic gathers, studying the signature characteristics of the anomalies, analyzing the various seismic anomaly scenarios and understanding the geologic risk factors are some of the salient steps that could be followed. Examination of amplitude anomalies from adjoining areas with similar geologic environment and the subsequent drilling results could help. All these steps, if performed logically and critically, could help lower the uncertainty in prospect evaluation. Exceptions may still surprise us.

Acknowledgements

The help extended by M. Garcia Torrejón in fixing the image shown in figure 2 is gratefully appreciated.

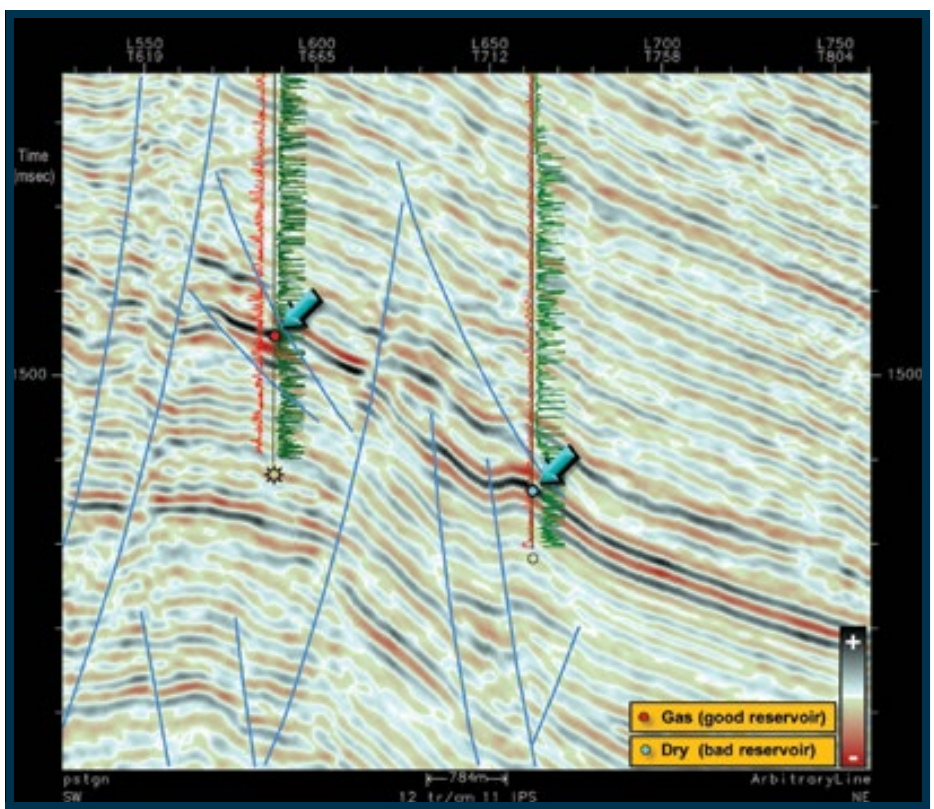

Figure 4: An arbitrary profile from a seismic data volume and passing through two wells. The well to the left is gas-bearing and the one to the right is dry. The reservoir level seems to be associated with similar geological and seismic amplitude levels. The overlaid curves are the spontaneous potential in red, and resistivity in green.

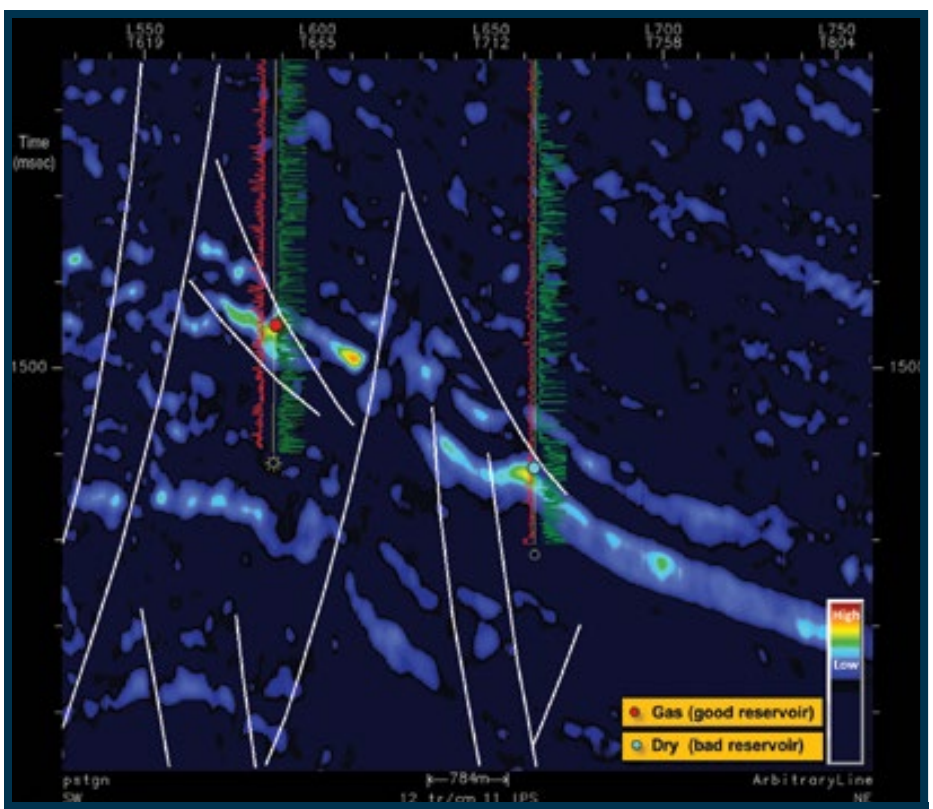

Figure 5: An arbitrary profile equivalent to the one shown in figure 4 from the reflection strength volume and passing through two wells. The reservoir in both the wells has similar reflection strength signatures even though one is gas-bearing (left) and the other is dry (bad reservoir). The overlaid curves are the spontaneous potential in red, and resistivity in green.

Bid Rounds Create Opportunities in Mexico

By EMILY SMITH LLINÀS, EXPLORER Correspondent

In a world with shifting politics, fluctuating commodity prices and economic uncertainty, Mexico's energy sector provides promise.

So affirmed Gaspar Franco, one of seven commissioners at Mexico's National Hydrocarbons Commission (CNH), the authority tasked with bidding, signing and regulating hydrocarbon contracts and advising Mexico's Secretary of Energy.

Addressing students and professors at the National Autonomous University of Mexico (UNAM)'s Earth Science Days in Mexico City recently, Franco explained how the nation's energy reform is transforming industry today and offering opportunities for the future.

From left are Emily Smith Llinás, AAPG; Nayeli Islas, CNH; Gaspar Franco, CNH; Pedro Avituá, AAPG Mexico Young Professionals Chapter; and Fernando Apango, UNAM AAPG Student Chapter.

Bid Rounds

"In Mexico we have everything that could exist, deep water, shallow water, shale gas and more," he said. "The geology is very diverse."

The government made a variety of fields available during Round 0, the bid round organized exclusively for state-owned company Petróleos Mexicanos (Pemex).

Franco explained how Round 0, held in August 2014, provided the opportunity for Pemex to select areas of interest for exploration and production. CNH awarded Pemex 100 percent of blocks requested for extraction and 67 percent of areas requested for exploration.

The next step was Round 1, a series of four auctions conducted over a two-year period.

Franco explained that the CNH wanted to strike a balance when deciding which contracts to auction. Offering large deepwater projects at the outset could create the impression that the government was only interested in attracting large foreign companies. Offering only small blocks could make some think that the reform was designed for small operators or Mexican companies only.

The solution was to offer a diversified round, with options available for large and small operators, he said.

At the time of the UNAM talk in November, CNH had completed three of four auctions in Round 1, which Franco deemed successful overall.

He noted that of the 44 contracted areas, 30 have been finalized and signed. Seven operators or consortia other than Pemex are producing in 23 areas.

"They are operating, paying royalties to the state and producing oil," he affirmed.

Deepwater Bid Round

The final phase in Round 1 focused on deepwater and involved several firsts, including Pemex participation.

"Obviously Pemex can bid whenever it wants, but the first time they decided to do so was in Round 1," Franco said.

The deepwater auction held Dec. 5 gave Pemex the historic opportunity to seek a partner to operate in the Trion field in deepwater Gulf of Mexico, near the U.S. border.

Franco noted that partnerships, prohibited prior to the 2013 Energy Reform, allow Pemex to operate like companies throughout the world.

"In these types of projects around the world, not even the largest companies operate alone," he said.

Five-year Plan

Round 2, initiated in July 2016, marked Mexico's first shallow water bid round. In bidding 1, CNH offers 15 contracted areas in the Tampico-Misantla Basin, Veracruz Basin and Sureste Basin. In bidding 2, CNH offers 12 contracted areas, nine in the Burgos Basin, two in the Chiapas fold belt and one in the Sureste Basin. In bidding 3, CNH offers 14 contracted areas in the Burgos Basin, Tampico-Misantla Basin, Veracruz Basin and Sureste Basin.

Round 2 is part of a five-year plan that the CNH has implemented to ensure that Mexico continues to develop reserves and to maintain financial stability long-term.

"We need to figure out how to have a margin independent of the oil price," he said.

During his talk at the UNAM, Franco projected maps showing more than 1,400 reservoirs, including black oil, volatile oil, gas condensate, wet gas and dry gas.

He described how the Commission aims to help Mexico reach its potential through the five-year plan, which is designed to help companies participate in production of both conventional and unconventional exploration projects.

Extraction projects focus on 237 oil fields: 169 onshore, 12 in Chicontepec, 39 in shallow water, four in deepwater and 13 heavy oil fields.

Exploration focuses on 72 conventional

See **Progress**, page 29

Monumental Wolfcamp Assessment First of Many

By KEN MILAM, EXPLORER Correspondent

One of the most productive regions in the petroleum world for almost a century, the Permian Basin is far from tapped out, according to a new U.S. Geological Survey (USGS) assessment.

The report, released in November, estimates that the Wolfcamp portion of the eastern Midland sub-basin contains 20 million barrels of oil trapped in West Texas shale layers, the largest such assessment ever made in the United States.

By some estimates, the oil is worth some $900 billion at today's prices, although the assessment did not attempt to determine whether producing the resources would be profitable.

"It's the first time we ever looked at it ... that was a first," said Stephanie Gaswirth, research geologist at the Central Energy Resources Science Center.

Gaswirth said she is already working on the next step: an assessment of the Delaware basin portion of the Permian, which lies in West Texas and New Mexico.

"If there are any operators who want to talk to me about the geology, we always welcome input from industry if they are willing to come in and chat with us," she said.

She expects that assessment to be completed sometime in 2018.

"It's a very productive area. It's not just oil, but oil and gas," she said.

As with the Wolfcamp project, "We go in and gather as much geologic information as possible. We rely on what's out there – literature, maps, drilling and production information databases."

"The (Wolfcamp) number means 20 million barrels of undiscovered, technically recoverable oil using today's technology," she said.

The Wolfcamp shale also holds an estimated 16 trillion cubic feet of associated natural gas and 1.6 billion barrels of natural gas liquids, according to the assessment.

The continuous oil estimate is almost three times larger than the agency's 2013 Bakken-Three Forks resource assessment.

"The fact that this is the largest assessment of continuous oil we have ever done just goes to show that, even in areas that have produced billions of barrels of oil, there is still the potential to find billions more," said Walter Guidroz, program coordinator for the USGS Energy Resources Program. "Changes in technology and industry practices can have significant effects on what resources are technically recoverable, and that's why we continue to perform resource assessments throughout the United States and the world."

Asked if the Wolfcamp findings were expected or surprising, Gaswirth said, "We (USGS) don't go in with any expectations. We were unbiased from a geologic standpoint. We have nothing at stake here."

New Tech, New Perspective

The Wolfcamp assessment was the first time the agency took a look at the Permian's unconventional resources.

"The last time was in 2007 and looked mostly at conventional resources," Gaswirth said.

Unconventional resources like those of the Wolfcamp are less well-defined, regional accumulations where the source rock is also the reservoir rock or in close proximity, she said.

It requires new technology like horizontal drilling and hydraulic fracturing, she said.

The methodology used for the assessment was standardized, as reviewed by the AAPG Committee on Resource Evaluation, she said.

"The Wolfcamp is source rock generating its own resource. It's a shale with high organic content. It's really thick compared to the Bakken — thousands of feet thick," she said.

Since the 1980s, the Wolfcamp shale has been part of the Wolfberry play that encompasses Mississippian, Pennsylvanian and Lower Permian reservoirs. Oil has been produced using traditional vertical well technology, the USGS announcement said.

However, more recently, oil and gas companies have been using horizontal drilling and hydraulic fracturing, and more than 3,000 horizontal wells have been drilled and completed in the Midland Basin Wolfcamp section, the agency said.

More to Come

The Wolfcamp shale assessment was undertaken as part of a nationwide project assessing domestic petroleum basins using standardized methodology and protocol, as mandated by Congress, Gaswirth said.

Gaswirth reiterated her "no expectations" approach in regard to the forthcoming Delaware basin assessment.

"We don't go in and say one region is better. We define the outer boundary then it's up to the industry where they put their wells," she said.

The Wolfcamp shale assessment is available online at usgs.gov.

"ProTracks" is an ongoing feature of the EXPLORER, offering news and information pertinent to getting started or getting better in your career. Keep up-to-date with the YPs on Facebook, Instagram, Twitter and LinkedIn.

A Win-Win for Science and Students

YPs hold first 'One-Day Tech Conference'

By MATT BOYCE, Gulf Coast Section Young Professional

"The current industry climate," "commodity prices" and "how to stand out" are just a few of the phrases commonly thrown around in discussions about the industry. Everyone seems to have their own take on how to navigate this environment.

However, one subject missing from the industry conversation is – not just discussing how to help those colleagues in transition or offering advice to students looking for jobs – but actually *doing* something about those challenges.

At least, that was the collective feeling at the 2015 Young Professionals (YPs) Leadership Summit.

So, in 2016, the AAPG Gulf Coast Young Professionals and the Houston Geological Society (HGS) NeoGeos decided to tackle two challenges that are close to our collective hearts and minds: showcasing technical excellence and giving back to our community.

First, we wanted to put on an event that would not only increase the visibility of local YPs, but also allow them to demonstrate their technical prowess in a forum that could enhance their career development. We thought this would be especially important for YPs who are between jobs and could use the opportunity to stand out to potential employers.

Our second goal was to offer some financial assistance to students and recent graduates. We decided that, while discussions and sessions with students about to enter the job market are useful, it is vital to attend recruiting events and other functions where there is an opportunity to interact with company representatives. Unfortunately, for most students, the principal barrier to attendance is financial. Since most of us on the Joint AAPG YP-HGS NeoGeos Committee are products of the AAPG Student Expo in Houston, and many of the Student Expos have been cancelled in recent years, we wanted to give back to that program.

YP Tech Conference at Southwestern Energy in August. Photo by Linda Sternbach.

The Dilemma

Now faced with the task of organizing an event that was part technical session and part charitable endeavor, we had an admittedly foreseeable, but no less daunting problem. To accomplish what we wanted seemed fiscally intractable, as anything we planned required money and, in the current price environment, it's in short supply. The challenge then became finding a way to provide a means to allow YPs to get technical recognition as well as financially support students, but without spending any money.

One mechanism to address this issue was my immediate realization that, as an industry, we have a significant untapped research resource in the form of undergraduate projects, master's theses and doctorate dissertations. Not only am I constantly using these student references for exploration and development projects – they also make up nearly 85 percent of the citations in my presentations.

The unfortunate part was that I knew very few of the referred authors who published their work in industry periodicals and peer-reviewed journals. I did a straw poll among friends and the general consensus was: "I did all that work in school, but after I graduated, it never saw the light of day again."

In that moment, it became apparent how we could give YPs the opportunity to present their technical work, even on our small budget.

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Birth of an Idea

This was the genesis of the first One-Day YP Tech Conference.

We theorized that most YPs, employed or in transition, would jump at the chance to present their university research. We also welcomed any company research being conducted by YPs, but acknowledged the challenge inherent in securing permission to present or publish potentially proprietary information.

With the support of Southwestern Energy, who generously donated their conference space at their headquarters in Houston, and sponsorships from the HGS NeoGeos and individual donors, the One-Day YP Tech Conference was held.

The concept was to have a one-day session where YPs would have 25 minutes to discuss their work. Most of the abstracts submitted were university studies, so management approval was not an issue. The conference was open to everyone, but only YPs could present.

We reasoned that limiting the conference to one day would not only boost attendance, as most people can spare one day away from the office, but also keep registration costs low. In addition, HGS allowed us to utilize their online meeting registration system, which helped keep the cost of attendance to a manageable $80 per person and a discounted $30 for people in transition.

The end result was great! We had excellent participation with more than 80 in attendance and an outstanding keynote address on petroleum economics by Tobi Odumosu of Citi Bank. The event attracted participants from multiple companies and job functions. The YP speakers expressed appreciation, not only for the opportunity to present their work, but to also practice their public speaking skills. Additionally, we exceeded our expectations by donating more than $1,500 to the 2016 AAPG Student Expo in Houston.

Something to Build On

The success of the 2016 One-Day YP Tech Conference has motivated us to continue this strategy by offering another one-day tech conference to raise money for the Student Expos.

Our hope is that these donations help decrease the cost of company sponsorship, allowing more companies to participate and meet some amazingly talented geoscientists. We think this is a good model not only for Houston, but also for other areas. There is a lot of great research out there that could benefit our industry. We aspire to continue to grow this program to include a YP journal that could present short technical articles from YP researchers worldwide.

In the end, our Joint AAPG YP-HGS NeoGeos Committee attributed the Tech Conference's success to the incredible support of our local society and corporate sponsors, and our passion for assisting students and colleagues in need.

Interested in hosting a YP Tech Conference in your area?

Visit us online at aapg.org/youngpros and contact your Region or Section representative, message us on our Facebook page at AAPG Young Professionals Special Interest Group or follow us on Twitter and Instagram at @aapgypsig.

Paul Strunk Awarded Foundation's Highest Honor

By TAMRA CAMPBELL, Administration Team Coordinator

Paul M. Strunk, this year's recipient of the AAPG Foundation's L. Austin Weeks Memorial Medal, is being recognized for something he's done consistently over the past three decades:


STRUNK

Provided valuable support and leadership to the AAPG Foundation – and through those efforts, provided valuable educational opportunities to an entire generation of geoscientists.

Strunk is the tenth recipient of this award, the Foundation's highest honor, given in recognition of extraordinary philanthropy and service directed to advance the mission of the Foundation.

"Deana (his wife) and I are proud to support and be involved with the AAPG Foundation," Strunk said after being told of the honor. "The Foundation has done an excellent job of providing funding for a vast array of educational and research programs that benefit society and the geologic profession.

"Now, to receive the Foundation's L. Austin Weeks Memorial Medal," he added, "is an awesome and tremendous honor."

Strunk will formally be honored April 2 in Houston, during the opening ceremony of the AAPG Annual Convention and Exhibition. And in winning the award he will join a Who's Who list of legendary supporters.


Deana and Paul Strunk

Past recipients include fellow AAPG Members Marta Weeks, T. Boone Pickens, Larry Funkhouser, Jack Threet, Bill Barrett, Bob Gunn, Jim Hartman, David Worthington and Bill Gipson.

His Path to Success

Paul and Deana have been donors to the AAPG Foundation since 1994, when he joined the Trustee Associates, a distinguished group of donors who provide support for the Foundation's fundraising efforts, as well as providing counsel and leadership to the Trustees.

It was the Strunks' belief in the new Military Veterans Scholarship program – and their lead gifts to its fundraising efforts – that made the program a reality for the Foundation.

In fact, in recognition of their commitment to the program, the Trustees recently renamed the program the Deana and Paul Strunk Military Veterans Scholarship Program.

Because of their generosity, the program is beginning its third year of accepting applications for scholarships from deserving veterans.

Strunk was selected as a member of the Foundation's Members of the Corporation in 2000 and appointed as a Trustee to the AAPG Foundation in 2011. During his time as a Trustee, Strunk also served on the Foundation's Audit Committee.

Strunk stepped down from the Board of Trustees earlier this year and is now a Trustee Emeritus.

Strunk, a successful explorationist and CEO of American Shoreline, in Corpus Christi, Texas, received his bachelor's degree from Kansas State University (KSU) in 1956, and began his career as a geophysicist with Pan American Petroleum Corp. One year later he returned to KSU for his master's degree.

He was then transferred to Corpus Christi, where he worked as a geologist for Pan American. In 1960 he joined Skelly Oil Company as an exploration geologist, and in 1964 he became independent geologist. He and an associate, J.B. Clark, formed Fontana Oil and Gas in 1974. Fontana merged with Centura Inc. in 1976, and Strunk became president of Centura.

In 1978 he resigned from Centura to start American Shoreline Inc., a successful oil and gas exploration company.

Continued on next page

Paul Strunk, president of American Shoreline (right) presents a $10,000 check on July 22, 2011 to Lisa Saenz, unit director for the Boys & Girls Club of Corpus Christi. Also pictured is the former Dallas Cowboys and Pro Football Hall of Fame legend Randy White.

Continued from previous page

A Career of Service

During his career in oil and gas exploration, Strunk has been involved with the discovery and development of over 36 oil and gas fields, most of which were in the Gulf Coast area of south Texas.

He has been an active Member of AAPG since 1960, serving on numerous committees and engaging in several leadership roles, including:

- Served as a two-term delegate in the House of Delegates
- Was a member of the Advisory Council
- Served on the Insurance Committee, Twenty-First Century Committee, Committee on Committees, Environmental Geology Committee, Headquarters Management Committee and Committee on Investments (chair in 1993-97)
- Held the office of AAPG treasurer (1988-90) and was a Candidate for President Elect (1994-95)
- Was a founding member of the Division of Environmental Geosciences and a member of the Division of Professional Affairs
- Received the AAPG Certificate of Merit in 1991 and the Distinguished Service Award in 1993

Strunk also has held numerous committee positions and offices for the Corpus Christi Geological Society and the Gulf Coast Association of Geological Societies, American Institute of Professional Geologists and Society of Professional Earth Sciences.

See **Career**, page 29

Foundation Contributions for November 2016

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Gretchen M. Gillis
In honor of David R. Cook
Larry L. Jones
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Military Veterans Scholarship Fund
Heather S. Anderson
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Matching gifts given by Richard Ball
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In memory of Toby Carleton
Edward and Elizabeth Heath
In memory of Toby Carleton
James L. Pear
Shell Oil Company Foundation
Matching gifts given by Alan Kornacki
John and Kate Spaid
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E.F. Reid Scouting Fund
Terri Duncan
Bryan Haws
Raymond P. Henkel
Grant from Dr. Raymond P. Henkel Charitable Fund at Fidelity Charitable

Visiting Geoscientist Fund
William M. Spindler

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

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

DIY Advocacy

By EDITH ALLISON, Geoscience and Energy Policy Office Director

A few days after you receive this EXPLORER the United States will have a new Congress and a new president.

Many of the new energy and environment decision makers will not be familiar with petroleum or energy science. Not just Americans, but people around the world are wondering what the new U.S. government is going to mean for their business and country. AAPG Members around the world can help provide scientific and technical explanations to help guide new legislation and regulation.

What follows are a few suggestions on how to gather information on the decision makers and issues, and on how to take action.


ALLISON

If you are visiting Washington... consider adding a visit with your senator or representative.

Reaching Your Representatives

Government websites are a great source of up-to-date, easy to use information. Your representative and senators have a page at House.gov and Senate.gov, respectively. Each legislator's page will describe their position on issues, sponsored legislation and how to contact them. Most will also invite you to subscribe to their e-newsletter.

There are many ways to get your opinion or data to your legislator. The fastest is to send an email using the legislator's website. Your note will go to the appropriate staff for action.

Taking time for several, more personal communications will be especially effective in gaining traction for your positions and the science behind energy issues. Start with a visit to your senator or representative's office, either in Washington, D.C. or in their home district – locations, schedules and meeting request forms are on their website. One note – do not be put off if your meeting is with a staff member rather than the legislator. Staff members are responsible for and knowledgeable about specific issues such as energy, and they will discuss your meeting with the legislator.

If you are visiting Washington for a family vacation or have a business trip on the East Coast, consider adding a visit with your senator or representative. If you are on vacation, you can even request a personal tour of the Capitol guided by your legislator's staff.

Tracking Bills

There is a mountain of legislation – tens of thousands of bills – introduced in state and federal legislatures, but there are user-friendly websites to help you find and track bills on specific topics. These sites will also identify the sponsors, whom you may wish to contact. To locate federal legislation on a particular topic use the search feature on the GovTrack website at govtrack.us.

For information on state legislation, a good source is the National Conference of State Legislatures, (NCSL), online Energy and Environmental Legislation Database, which allows searches by state, topic or keyword.

News and policy statements from the president's administration are available online at the White House website. In addition, all federal agencies (with the exception of intelligence and defense agencies) provide online organization charts with contact information. You can expect a reply to your email – these people work for you.

Regulation

The executive branch implements regulations under laws such as the Clean Air Act, Safe Drinking Water Act and the Federal Land Policy and Management Act.

Regulations coming from executive branch agencies, especially the Environmental Protection Agency and the Department of the Interior probably affect the petroleum industry more than new legislation. Many planned regulations will be described in press releases from the agency. In addition, oil and gas trade associations will explain their position on new regulations that affect the industry.

The government has websites that provide even more information on regulations and allow you to submit comments during the 30-90 days that draft regulations are open for comment. The website reginfo.gov has an easy to understand introduction to proposed regulations and details about planned regulations. If you see something of concern at reginfo.gov or on the evening news, go to regulations.gov to submit comments.

Government Research

The government is much more than regulations. For more than a century, the federal government has conducted research and supported academia and government-industry partnerships to advance petroleum exploration and production technology. In addition, explorationists, environmentalists and infrastructure planners value the U.S. Geological Survey (USGS) mineral and petroleum resource assessments. Federal petroleum technology research and development are conducted by agencies

Continued on next page

Career
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A Career of Giving

Strunk's philanthropy and service does not stop with the AAPG Foundation; he actively supports the geology program of his alma mater KSU.

Specifically, the Strunks provide support to KSU to the geoscience building program, the Strunk Geology Fellowship and other geology funds. Strunk has served on the KSU Advisory Council for the Department of Geology and is a member of the Presidents Club.

"Kansas State and the Kansas State Foundation are incredibly grateful for the generosity and leadership the Strunks have demonstrated through their continuous support," said Shelia J. Walker, the KSU Foundation's senior director of development.

"Paul is very deserving of the AAPG Foundation's L. Austin Weeks Memorial Medal," she added, "and thank you for renaming the Military Veterans Scholarship after the Strunks."

In addition to his professional activities, Strunk has been active in civic and governmental affairs:

- He supports a number of charities in his local area, which focus primarily on programs for children and families.
- He has served on the Corpus Christi Independent School District Building Advisory Committee and on the oil industry segment of the United Way Committee.
- In 1996 he was appointed by the governor of Texas to serve on the Committee for Property Tax Relief.
- He currently is serving on the Energy Resource Committee of the Interstate Oil and Gas Compact Commission, and is a member – and has served on the executive committee – of the Texas Independent Producers and Royalty Owners Association.

In other words, a lot of people have a lot of reasons to be grateful for Strunk's commitment, dedication and philanthropy. That goes doubly for the AAPG Foundation.

Progress
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areas: 29 deepwater, 17 shallow water, 26 onshore and 24 unconventional areas including five in the Burgos Basin, two in Burro-Pachos and 17 in Tampico-Misantla.

The fields available provide numerous opportunities both for Mexican companies familiar with the geology and foreign companies bringing outside expertise to areas not previously explored.

Benefits of the Reform

Franco noted that progress is being made, and quickly.

"In the past two years, we have had more seismic run than in 70 years prior," he said.

He explained how, in addition to opening Mexico to outsiders, the country's energy reform provides benefits to Mexican companies.

Of the 37 companies who participated in the first three Round 1 auctions, 24 were Mexican. Companies from eight other countries help Mexico by assuming financial risk for projects and by bringing in local operators.

"This is a business. When other companies risk their capital the (Mexican) government doesn't have to risk its own," he said. "Who runs the seismic registries? Who gets the oil out of the ground? Who brings the rigs in? The foreign companies work with local companies."

He noted that Mexican companies benefit from the federal government's policy of promoting national content.

The "Made in Mexico" legislation, adopted in 2009, requires companies operating in Mexico to purchase goods and services in order to promote the use of national products.

The policy provides an opportunity for aspiring entrepreneurs, even recent graduates, Franco said.

Challenges and Opportunities

Franco urged against discouragement from the current low price environment and noted that geoscientists and engineers have a key role in helping the country develop its energy potential.

"We need to understand naturally fractured reservoirs. We have to understand the reservoir in order to extract the hydrocarbons. We need to reach out to the local communities in areas where we are looking for shale oil and shale gas," he said. "People have questions, and geoscientists can help to answer them."

Franco also highlighted opportunities for wells that have been operated since 1900 and need strategies for well abandonment.

"In Mexico, we don't have a single project involving secondary or enhanced recovery yet," he said. "The projects may be expensive now, but we have to be ready so we can move forward when prices go up. They're not going to be this low forever."

Mexico is a great place to work and do business, Franco said.

"People have said there is no work, there are no employment opportunities in Mexico, but now we have many companies interested in doing business in Mexico," he said.

Continued from previous page

like the National Science Foundation, the USGS and the Energy Department. These agencies' websites have data-rich project reports that may suggest new exploration targets.

AAPG's D.C. Office

I want to thank the many AAPG Members and staff that contributed to the success of AAPG's Washington, D.C., office, GEO-DC. It started more than a decade ago with a multi-year effort by AAPG Members concerned that Washington decision makers needed to hear about the science behind petroleum exploration and production. Don Juckett, the founding director, opened the office in 2005. David Curtiss took over in 2007. Shortly after David moved to Tulsa to become AAPG's executive director, I joined the office. It has been a wonderful opportunity.

Beginning this month, AAPG will no longer have staff working full time in Washington, D.C., so this is my final Policy Watch column. I have greatly enjoyed the support and camaraderie of AAPG Members interested in policy or curious about the ways that the federal government operates. I will continue to be an active Member of AAPG, so I look forward to seeing many of you at meetings and conferences.

I hope to see you in Houston to kick off our second century!

IN MEMORY

Robert Cluff
Denver, Colo., Oct. 26, 2016
Stanley King, 89
Humble, Texas, Oct. 13, 2016
William Arrington, 59
Houston, Texas, Oct. 26, 2016
Robert Odell, 90
Casper, Wyo., Oct. 21, 2016

(Editor's note: Due to an error in our records, last month's "In Memory" report of John Humston's passing was greatly exaggerated. Thankfully, he is alive, and we apologize for the mistake.

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

DPA
from page 30

to be the largest ever estimated for an unconventional oil play in the United States.

The startling fact is that perhaps the largest oil and gas fields ever discovered in the United States have been brought to market within the past decade by geoscientists working in areas long thought to have been played out, thinking creatively for opportunities to reinterpret old paradigms, and recognizing and separating what is known from what is unknown.

These events demonstrate that Pratt's philosophy is as valid today as it was in 1952.

Passing Along Our Heritage

As AAPG celebrates its 100th anniversary, it is timely to honor the central role that creative geoscientists have played in bringing new hydrocarbon resources to market, and to motivate the next generation of geoscientists with a rich legacy of lessons learned to help them properly apply Pratt's philosophy for the next 100 years.

To this end, the annual Division of Professional Affairs (DPA) luncheon will present a sequel to the 2002 "Heritage of the Petroleum Geologist" luncheon titled "Toward a Philosophy of Oil Finding: Then, Now, Tomorrow!" The DPA will honor 58 accomplished geoscientists, bringing the total of recognized honorees from the two combined events to 101: 100 to celebrate AAPG's centennial, plus one additional individual to symbolize the passing of our deep heritage to the next generation of petroleum geoscientists. Attendees will also receive a print edition of our 2017 Heritage Volume that summarizes our honorees' experience – including successes, disappointments, anecdotes and advice.

My thanks to Charles Sternbach, Andrea Reynolds, Bob Shoup and Diane Keim for their efforts to bring this event together. We hope that you will mark April 4 on your calendars for the DPA Heritage Luncheon at the 2017 ACE!

CLASSIFIED ADS

DIRECTOR'S CORNER

Revealing the Past, Focusing on the Future

By DAVID CURTISS

Under a dark sky shimmering with stars, a little boy and a tiger stand together, staring upward.

"Do you believe our destinies are determined by the stars?" asks the little boy.

"Nah," replies the tiger.

"Oh. *I* do."

"Really? How come?"

"Life's a lot more fun when you're not responsible for your actions!"

The boy philosopher from this April 9, 1988 comic strip is, of course, Calvin, who along with his pet tiger Hobbes were the creation of cartoonist Bill Watterson and charmed their way into our collective consciousness beginning in 1985.

I was recently flipping through Calvin and Hobbes cartoons and was struck by how often Watterson returned to this scene under the stars. Another poignant one (Oct. 14, 1993) has Calvin standing alone, stars twinkling above him.

"I'm significant!" he cries, looking skyward. Then mumbling to himself, "screamed the dust speck."

I can relate to this emotion.

In fact, I vividly recall the first time I saw the Milky Way. It was at geology field camp, just prior to graduating college. I had spent much time outdoors as a child and seen many stars, but I had never been as far from light pollution as I was that evening in the Black Hills of South Dakota.

Stepping off the dormitory porch I saw a bright band of stars spanning the horizon, and experienced our home galaxy living up to its name, the Milky Way. There is something about standing under the stars that prompts reflection, as Calvin experienced, and yields to broader perspective. As you look to the nighttime sky, you're looking back in time – into history. The light bouncing off your retina has been traveling for thousands, perhaps millions of years.


CURTISS

> "... we may have made it look too easy, because as anyone who's drilled an exploration well knows, this is a story of not just smarts, but also vision, grit, determination and luck."

As geologists, we're used to dealing with time frames that are difficult to fathom on a human scale. Staring into the cosmos, you experience them at a whole new level. And for millennia the scientists of the day studied, surmised and were drawn to the heavens.

In more recent times, the stars became a symbol of the future. Beginning with the Apollo program in the 1960s and accelerated today by billionaires like Elon Musk and Jeff Bezos, who see humanity's future in the stars, there is a feeling of hope and promise of new frontiers to explore.

The stars above both reveal the past and draw us toward the future.

And that's an apt metaphor for AAPG this year as we celebrate 100 years of professional petroleum geology.

The Next Chapter

It's appropriate that we look back into our history. After all, our science is built on the foundation of those who went before us, observing, measuring and intuiting earth processes. We're still learning and refining our understanding.

Finding and producing oil and natural gas is also a commercial venture. We do it because petroleum is the energy source that underpins the modern world. Without it, we would have never gotten to the moon. Without it, we'll never get to the stars.

But we may have made it look too easy, because as anyone who's drilled an exploration well knows, this is a story of not just smarts, but also vision, grit, determination and luck.

As we celebrate this year, we will pay homage to the greats of our profession – those who went before us and those who are still among us. We want to learn from their experience and to be inspired by their example, but we don't want our focus to be anchored in the past.

Instead, we want to pull your eyes forward.

There's a new chapter to be written, there are new stories to be told. There is more oil and natural gas left to find. Explorers are optimists. They look to the future.

Let's Go Exploring

After a decade of drawing "Calvin and Hobbes," Watterson decided it was time for him to move on, to begin a new chapter of his career. And at this time of year, a time of new beginnings, I'm reminded of his last cartoon featuring the boy philosopher and his stuffed tiger, published Dec. 31, 1995.

Calvin is breaking a trail through freshly fallen snow, Hobbes in his wake carrying a toboggan.

"Wow, it really snowed last night. Isn't it wonderful?" Calvin exclaims.

"Everything familiar has disappeared," Hobbes replies. "The world looks brand-new!"

"A new year…a fresh clean start!"

"It's like having a big white sheet of paper to draw on!"

"A day full of possibilities!"

Climbing aboard the toboggan, Calvin turns, "It's a magical world, Hobbes, ol' buddy…"

And as the toboggan swooshes down the mountain he continues, "…let's go exploring!"

DIVISIONS REPORT: DPA

Celebrating Our Heritage

By CHANDLER T. WILHELM, DPA President

As many readers already know, AAPG will celebrate its 100th anniversary at the 2017 Annual Convention and Exhibition in Houston. While 100 years is a great milestone, it is also true that our profession is younger than the other scientific professions that serve as cornerstones of our modern industrial society. It is possible to track the history of other scientific professions for millennia – think of civil engineering and the Romans, for example.

So, despite frequent predictions of the end of the hydrocarbon era, it is entirely possible that our profession is still in its early and formative stages, and that geoscientists of the future will continue to play a vital role in providing the energy that powers the industrial world.

It is undeniable that the success of our profession has been enhanced by the revolution in technology and computing capability that have impacted all aspects of modern life. I would also suggest, however, that our continued success in finding and developing new hydrocarbon resources reflects much more than improvements in the tools of our trade. Instead, I think the ability to find and economically develop new hydrocarbon resources requires adherence to some fundamental principles that underpin what successful geoscientists have done in the past, do now and will continue to do in the future.


WILHELM

> The largest oil and gas fields ever discovered in the United States have been brought to market within the past decade by geoscientists working in areas long thought to have been played out.

Embracing the Unknown

Founding AAPG Member and former chief geologist for Humble Oil Company, Wallace Pratt, summarized these principles in 1952 in one of the classic petroleum geology papers ever written, "Toward a Philosophy of Oil Finding."

Pratt described the inherent conservatism of the trained scientific mind, and how this has caused the most well informed geoscientists of each generation to constrain their thinking to what was known, and to dismiss what was unknown. He cited specific examples of the best geoscientists of their respective eras failing to predict vast amounts of oil and gas that were later discovered because of their inability to expand their thinking beyond what was known at the time.

To quote Pratt: "There exist more formidable barriers to success in oil-finding than the lack of perfected methods and techniques of exploration: the ultra-conservatism of the trained scientist and engineer, (and) the tendency of the human mind to discount or to ignore the significance of what remains unknown to it."

He then went on to summarize his philosophy in his now-famous statement (paraphrased for modern times): "Where oil is first found, in the final analysis, is in the minds of (explorers)."

There is probably no better example of the timelessness of this statement than today's unconventional oil and gas revolution, which has dramatically changed the outlook for world oil and gas supplies in ways that were inconceivable only a decade ago. One need look no farther than Pennsylvania, the site of the world's first oil well (the Drake well), to get a modern example of Pratt's philosophy in action. During the early 2000s, the accepted wisdom of the most knowledgeable experts in the United States predicted that the main natural gas supply basins would continue to be the Gulf Coast and the Rockies, and that LNG imports would eventually be required to balance growing market demand. Fast-forward 15 years and the industry has witnessed what is arguably the most dramatic resource development story anywhere on the planet in the Marcellus and Utica plays, which have grown gas production from only about 1 bcf/d in 2008 to about 22 bcf/d in 2016 (or approximately 30 percent of the North American market). The Marcellus play alone (at about18 bcf/d) now produces more gas than any other country in the world except for Russia, making Pennsylvania arguably the largest gas field on the planet.

To demonstrate that the Appalachian Basin is not a "one-off" fluke, the Permian Basin provides a corollary example for oil. Oil was first discovered in the Permian in 1921 and by 1976 reached a peak production of approximately 1.5 mmbo/d, after which it went into a 30-year decline as conventional fields matured and capital went elsewhere (mainly offshore) in search of larger fields.

By the end of the century, the basin was considered played out for new discoveries.

All of that changed with the advent of horizontal drilling and multistage fracturing, and by 2016 the Permian reached a production level of about 2 mmbo/d. In November of last year the United States Geological Survey announced its updated Mean Technically Recoverable resource assessment for the Wolfcamp shale in the Midland Basin of approximately 20 BBO

See **DPA**, page 29

still jamming

We are still here rocking and rolling with new additions to our library across the US, Canada, & Mexico.

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