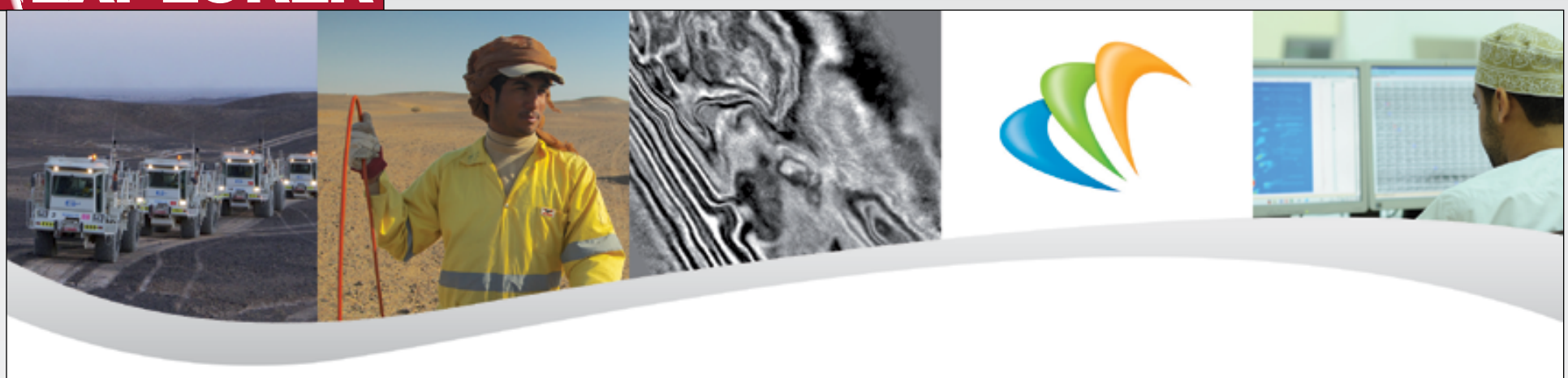
AAPG EXPLORER

FEBRUARY 2016

The Great Flood

The global oil oversupply persists, production increases.

See page 14



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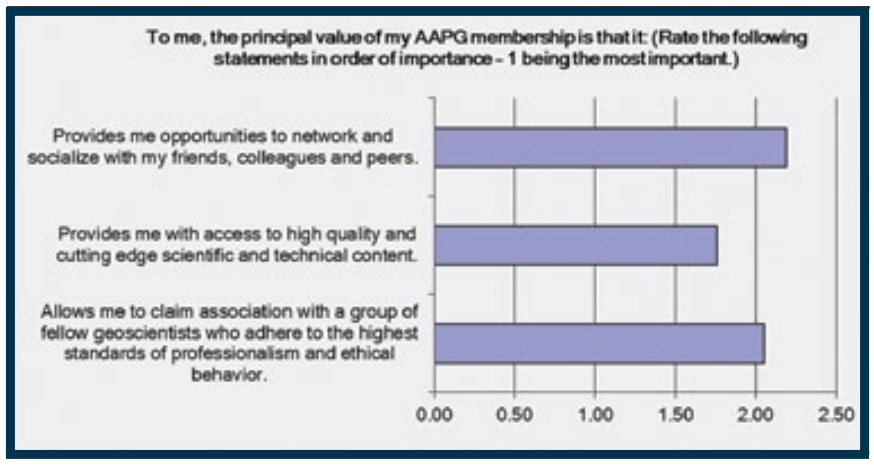
Vol. 37, No. 2
February 2016

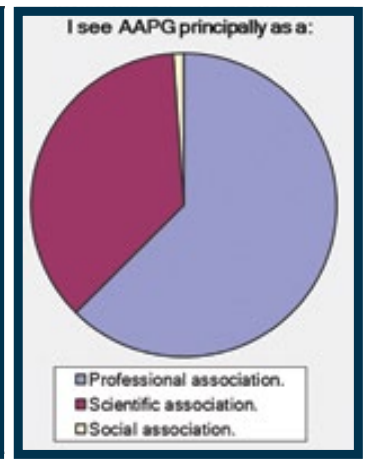
AAPG EXPLORER

PRESIDENT'S COLUMN

What is AAPG ?

By BOB SHOUP, AAPG House of Delegates Chair





As I have met with delegates and AAPG leaders around the world, there has been considerable discussion about what AAPG is, or should be. There are many who believe that AAPG is, and should remain, an association that stands for professionalism and ethics.

This harkens back to one of the key purposes of founding AAPG in the first place. One hundred years ago, there were many charlatans promoting drilling opportunities based on anything but science. AAPG was founded, in part, to serve as a community of professional petroleum geologists, with a key emphasis on *professionalism*.

Many members see AAPG as a scientific association. Indeed, AAPG sees itself largely as a scientific association. One of the Association's strategic goals is to be the premier scientific association for petroleum geoscientists.

When I joined AAPG several decades ago, being able to access quality geoscience papers was one of the key values to my membership. AAPG's technical programs and publications, short courses, Datapages, UDRIL and Search and Discovery go a long way in meeting that strategic goal. However, the amount of information available to all on the Internet makes it easy for any geoscientist to access quality geoscience papers without being a member of AAPG.

Still others see AAPG as a social organization where they can meet with their colleagues. To them, the value of AAPG is in the social networking opportunities it offers at conferences, field trips and education events.


SHOUP

AAPG faces a number of challenges as we move into our Association's second century. We can't afford to be everything to everybody, which means we will need to be selective in the types of services we continue to offer our members. Knowing how the members view the Association will help the EC prioritize the services we offer.

Instead of regaling you with my opinion, I have asked for the opinion of several hundred past, present and future leaders of the Association – 88 responded. The first question they were asked, was to rate what they consider to be principal value of AAPG membership.

At first glance, it appears that our leaders are nearly equally divided that AAPG is a social, scientific and professional association. However, when asked how they view AAPG, the answer was overwhelmingly that they view AAPG as a professional and a scientific association.

When reviewing the comments, which are available on AAPG's website, it becomes apparent that what our respondents value about professionalism does not lie in the area of ethics and professional standards, but in the ability to network with like-minded professionals.

These networking opportunities allow our members to discuss the science, and to become aware of business opportunities.

They do not view these networking opportunities as social functions, although they often revolve around social settings such as receptions and icebreakers.

What does this survey tell us about the types of services AAPG should focus on providing to our members? As I read the comments provided by those who responded to the survey, it seems that AAPG should primarily focus on two main areas: continue to provide high quality scientific content to our members and to increase opportunities for our members to network with their professional peers. Ideally, we can address these two priorities together.

Our annual meeting (ACE) and our international meetings (ICE) provide high-quality scientific content and professional networking opportunities. However, we can host more regional Geosciences Technology Workshops (GTWs) and Hedberg conferences. These types of smaller conferences can also provide excellent scientific content and professional networking opportunities.

Another priority for the Association leadership should be to leverage Search and Discovery as a means to bring professionals into AAPG. Search and Discovery is an incredible resource, and free to all geoscientists.

We must look for ways to make Search and Discovery, along with our other online scientific products such as Datapages an invaluable service to our members. Not only will this be a direct benefit to our members, but a service to all geoscientists that can help us grow our membership base.

I believe that by focusing on these priorities we will go a long way toward making the AAPG the Association that advances petroleum geoscience.

What do you think? You have an opportunity to let us know by taking the same survey that the AAPG leadership took by visiting www.surveymonkey.com/r/LeadershipSurveyJanuaryExplorer. We look forward to your comments and opinions.

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The Sarawat Mountains as seen from the city of Ta'if in the Mecca Province of Saudi Arabia. The Sarawat range is the largest mountain range on the Arabian Peninsula and stretches from the Jordan border to Yemen. Photo by Futuristical Tee.

Left: Geologists measure a section through the Triassic Shublik Formation along the Sadlerochit River near the eastern end of Sadlerochit Mountains, northeast Brooks Range. See story on page 8. Photo by Dave Houseknecht.

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Publications Pipeline Program Reaches Major Milestone

By KEN MILAM, EXPLORER Correspondent

AAPG's Publications Pipeline program does more than funnel books and publications to understocked and underserved universities and libraries.

It pumps a lot of good will along the way, explained Jon Blickwede, AAPG member, senior advising geologist for Statoil and former chair of the AAPG Publications Pipeline Committee.

The committee was launched in 2000 with the aim of distributing geoscience and engineering books and publications to universities around the world that lacked those resources.

Blickwede said committee founders Mark Cassidy and Rick Wall of Amoco began the project, knowing companies, individuals and institutions had a number of publications they needed to clear out, but didn't want to simply throw away.

Most of the material consists of donations from retired and deceased geoscientists and downsized company libraries, he said.

The works are gathered in Houston, the committee's base of operations, then sorted, cataloged and parked. Once a need is identified, arrangements are made to ship them, often via companies with interests in those countries.

The effort began slowly, but has grown steadily over the years. Blickwede said the PP took 13 years to pass the 100-ton milestone. But in only two years since, the program already is fast approaching 200 tons. Late last year, the Publications Pipeline Committee held a gathering in Houston celebrating 161 tons of donated publications.

Since its inception, the pipeline has delivered publications to about 60 universities in at least 15 countries on every continent except Antarctica, Blickwede said.

Myanmar Milestone

In another milestone, the PP made its largest single shipment last year to universities in Myanmar.

The AAPG Asia Pacific team was able to secure sponsorship for the logistics required with the generous support of Chevron, Statoil and Schlumberger, according to Peter Grant, president of AAPG's Asia Pacific Region.

Grant said the initiative began at the first AAPG conference in Yangon in August 2014, and the books were formally presented during the second AAPG/EAGE/MGS Myanmar Oil and Gas Conference on Nov. 18, 2015, Grant said.

Some 33,000 kilos of books on 60 pallets had been delivered to Yangon University prior to the official presentation, and were to be distributed to the various participating universities in the system.

Blickwede, who championed the shipment for the PP, said the collection would fill a shelf more than a kilometer long and was by far the group's single-largest delivery.

"It was very pleasing to see many students attend and to see how they had so much interest in the event and the books," Grant said.

"The volume of books was very impressive and were a combination of old and new textbooks from around the world, field and case studies, memoirs and journals," he said. "All seemed to be of high quality."

The significant task ahead is for the university to catalogue the books and then make them available for students and the

See **Large Shipment**, page 6

AAPG Deputy Executive Director David Lange (left), Martin Cassidy (middle) and Art Browning (right) with the Cambodian Institute of Technology Certificate of Appreciation at the recent gathering in Houston. Photo by Brian E. Wall.

Students in Myanmar celebrate a massive delivery from the AAPG Publications Pipeline program. Photo by Peter Grant.

multi-client seismic

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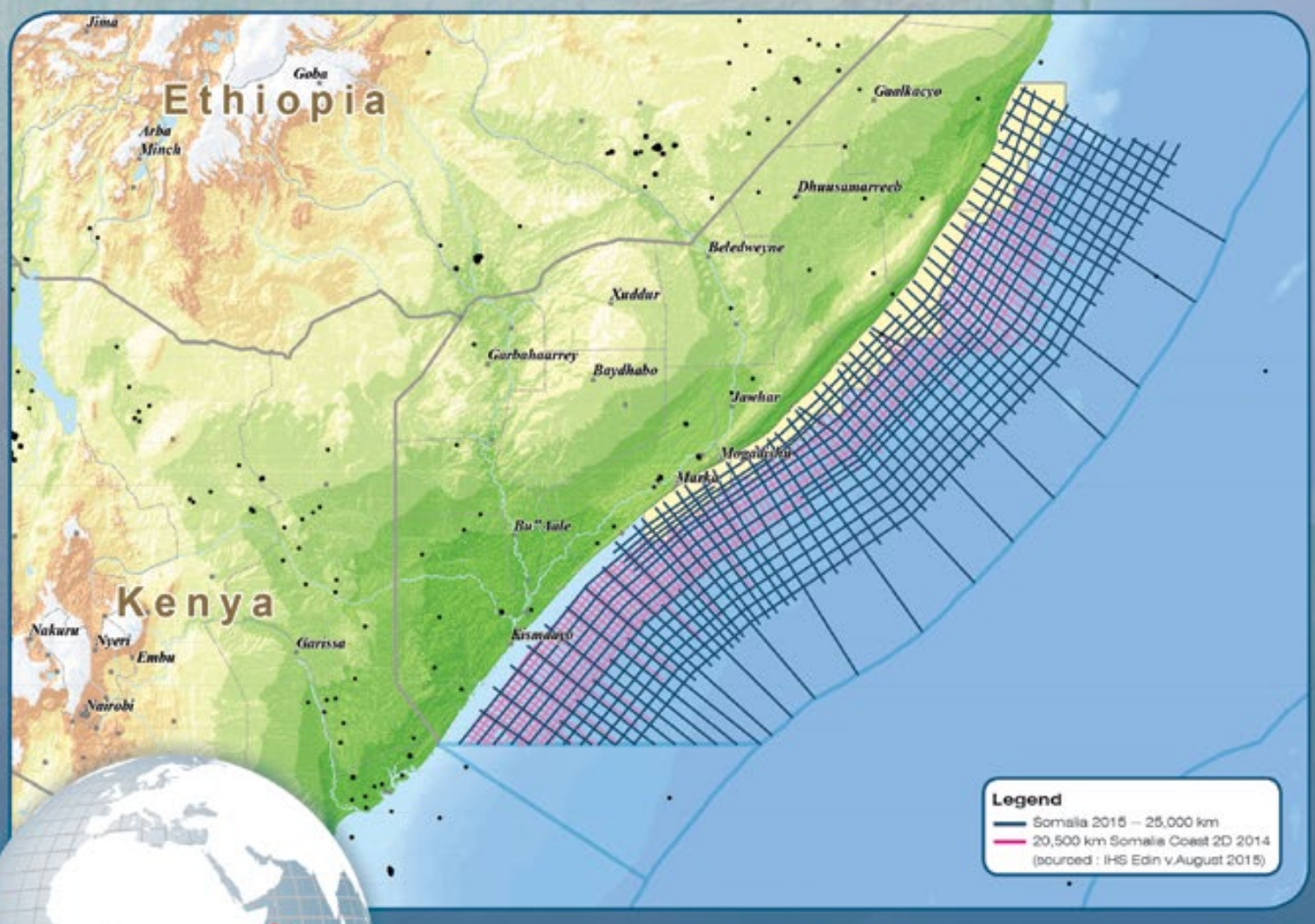
Somalia Unlocked

New 2D Multi-Client Seismic Unlocks Potential



During Q4 2015 Spectrum entered into a co-operation agreement with the federal government of Somalia to acquire approximately 28,000 km of modern 2D seismic. Seismic acquisition began toward the end of 2015 and completion is expected in early 2016.

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

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

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Large Shipment
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other participating universities. We wish them well in this huge project," Grant added.

Blickwede called the PP efforts a "definite win-win," providing needed resources for students and "a good public relations effect for AAPG and the companies that arrange to pay for the shipments. Often they have operations in the receiving countries and the deliveries can fill some community support obligations they may have."

Africa

Another large shipment is championed by committee volunteer Elizabeth Desser to Lubumbashi, Democratic Republic of the Congo, Blickwede said.

He said the shipment probably would fill 20 pallets and be the group's second-largest delivery to date.

"Elizabeth spent time in the Peace Corps in east Africa and has been working through those contacts to contact universities there," he said.

While, like many countries, the Democratic Republic of the Congo "is not the easiest, security-wise," Desser found a shipper agreeable to making the deliveries, Blickwede said.

The PP's core work group meets for a monthly work session in Houston, mapping plans and doing the physical work of inventorying, packing, loading and labeling donated publications.

Both Blickwede and Desser said the sessions are fun and, Desser noted, "a great upper body workout."

The group has about 12 core workers. Blickwede said some newer volunteers bring a lot of enthusiasm and energy to the program.

"While many of us take for granted online access and digital media, those means are not easily accessible in many countries," Blickwede added. "They still treasure old-fashioned books and journals."

And, he explained, the Publications Pipeline program itself will continue to be treasured for years to come.

"It's a way to pay it forward to a new generation of geoscientists," Blickwede said. "AAPG fosters new up-and-coming petroleum geologists around the world and helps establish itself as an international entity, growing the profession and the membership."

Know your Benefits, Save on Dues

By VICKI BEIGHLE,
AAPG Member Services Manager

Our industry is once again experiencing a downturn; and AAPG is aware that many of our members have been negatively impacted by low oil prices. Now more than ever it is important to maintain networking connections by maintaining your membership, and AAPG's graduated dues structure may help you stay connected.

Qualifying members can save up to 75 percent on basic-full member dues. If your annual personal gross income is between $25,000 and $50,000, you qualify for 50-percent savings ($52.50 annual dues). If your annual PGI is less than $25,000, you qualify for 75-percent savings ($26.25 annual dues).

Delinquent members who need to renew dues for the current 2015-16 fiscal year can make the change online as they remit payment. Current paid members who qualify can utilize the same opportunity (change online) when we begin our annual billing for fiscal year 2016-17.

Unlike other organizations that tie annual dues to World Bank categories, AAPG dues are based on the individual member's ability to pay.

Our purpose in creating this dues program was to ensure no geoscientist would be denied participation because of a financial situation. With the graduated dues program, those who are currently unemployed and/or seeking employment have the opportunity to maintain their membership with a maximum discount up to 75 percent.

As a cost savings measure to the organization, publication options reflect the level of dues paid; however, all paid members continuously receive access to the EXPLORER and BULLETIN, and more importantly, all other member benefits (networking, our online career center, member discounts, etc.)

While members must qualify for the reduced dues, no proof is required of any member's PGI; this system is honor-based and defined by our standards of professional conduct.

Members must qualify and request lower dues annually; verification of income level is required by electronic signature for online payments, and/or by initialing special dues billing form.

Additionally, AAPG offers Emeritus membership, which not only saves (voting) Members 50 percent on annual dues (including certification dues), they also receive 50-percent savings on AAPG's annual ACE and ICE meeting registrations for both themselves and their spouse/guest's registration.

Members must be 65 years of age, and have a minimum of 30 years cumulative membership. In accordance with our bylaws, qualifying members must request this classification change.

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Below: View to the west in Ignek Valley, with Shublik Mountains on the left and Sadlerochit Mountains on the right. Exposure in foreground along Hue Creek includes Cretaceous strata of the dark gray pebble shale unit and the multicolored Hue Shale, both of which are source rocks beneath the North Slope.

Photos by Dave Houseknecht, USGS

Where Did Shell Go Wrong in the Arctic?

By HEATHER SAUCIER, EXPLORER Correspondent

With Shell abandoning its exploration plans in the Chukchi Sea in September and Statoil following suit in November, many might believe that the North Slope Basin off the northern coast of Alaska has been condemned.

Yet those who have put decades into studying the geology of Alaska's North Slope and Outer Continental Shelf believe the opposite.

The Bureau of Ocean Energy Management estimates that in terms of undiscovered, technically recoverable conventional resources, the Chukchi Sea contains a mean of 15.4 billion barrels of oil and a mean of 76.8 trillion cubic feet (Tcf) of gas.

And, finding those resources may very well boil down to understanding a geological phenomenon that might have offset past exploration programs in the region.

"The story in the Chukchi is highly compelling, but it's hard to get anyone to talk about it," explained David Houseknecht, AAPG member and senior research geologist, and project chief for the Energy Resources Program in Alaska for the U.S. Geological Survey (USGS).

"If you just read the pop literature about Shell and Statoil pulling out, you might think the offshore Arctic has been condemned," he said. "But in my mind, nothing could be further from the truth."

HOUSEKNECHT

> **"If you just read the pop literature about Shell and Statoil pulling out, you might think the offshore Arctic has been condemned. But in my mind, nothing could be further from the truth."**

Why Shell Left

There are many theories about why Shell scrapped its plans for exploration in the Chukchi Sea after its Burger J well, drilled roughly 80 miles offshore the western end of Alaska's North Slope, didn't deliver.

Marvin Odum, director of Shell Upstream Americas, gave only the barest explanation in a press statement last year: "Shell will now cease further exploration activity in offshore Alaska for the foreseeable future. This decision reflects both the Burger J well result, the high costs associated with the project, and the challenging and unpredictable federal regulatory environment in offshore Alaska."

According to AAPG member Mark Myers, commissioner of Alaska's Department of Natural Resources (DNR), Shell's Burger J well – located in the 25-mile diameter Burger structure – was located in a tremendous geological prospect, but it appears it was not associated with an oil leg.

Shell explained that its findings were "not sufficient to warrant further exploration," as reported in The New York Times.

Some Alaska geologists say Shell ran out of patience. Others say the current price of oil could not sustain its exploration program. Others point toward the federal government's stringent drilling requirements – the mandate for a second rig to be on site for a relief well – being the most costly.

While no one can speak for Shell besides Shell, Houseknecht, who has studied Alaska's faults and folds for decades, can speak for the lay of the land – at least his interpretation of it. He believes that, had Shell aligned its exploration plans with a certain geological hypothesis, which purports that a tremendous amount of gas from the foothills of the Brooks Range displaced oil accumulations in the Burger structure, it might have struck oil by drilling farther west.

A Well-Placed Well

In the eyes of Myers, Shell drilled in a location that met the geological checklist for oil. The Burger structure boasts a good source rock, an oil and gas charge and a solid reservoir rock with a seal and a large gas cap estimated at a mean of 14 Tfc in a 2004 U.S. Bureau of Ocean Energy Management's Minerals Management Service report.

"I believe Shell's goal was to move downdip of the gas cap to see if there was an oil leg," Myers said. "But based on their statements, they didn't."

Geologist examines steeply dipping, overturned contact between Jurassic Kingak Shale (left) and Lower Cretaceous Kemik Sandstone, which is overlain at right by Lower Cretaceous pebble shale unit. This outcrop, along Hue Creek at the northern front of the Shublik Mountains, northeast Brooks Range, preserves the same stratigraphic relationship that extends across much of the North Slope and Chukchi Shelf. Light colored rocks at upper left are Proterozoic Katakturuk Dolomite, thrust northward over the Kingak Shale.

While it is common to drill near known accumulations of gas, the complex geologic history of the North Slope and offshore Alaska can turn that strategy into a bust.

On a map, Houseknecht pointed to the world-renowned Alpine field, which was discovered in 1994 in the Colville River Delta.

"It remains the largest onshore accumulation discovered in the last 30 years in the United States, and it is almost certain to produce more than 1 billion barrels of oil during its lifetime," he said.

Yet, to the west, within just 30 miles of the Alpine field, is the Hunter well – drilled by ConocoPhillips in the early 2000s – which surprisingly produced only gas.

"Everyone knew from seismic and other data that the same geology of the Alpine Field extends westward into NPRA (National Petroleum Reserve, Alaska). But over an astoundingly short distance, mostly gas was found," Houseknecht said.

Following the map westward, Houseknecht pointed to a cluster of gas wells in NPRA at the Walakpa Gas Field, which was discovered by the federal government in 1980. An adjacent well, the Intrepid, was drilled downdip from the gas field by ConocoPhillips in 2007 – presumably to test for presence of an oil leg, Houseknecht said. While the geology in NPRA more than hinted that an oil leg might be present, the Intrepid found no oil and was abandoned.

A study of gas geochemistry published by the USGS in 2003 found that the Walakpa gas field contains the most thermally mature gas on the North Slope based on carbon isotope data, suggesting that the gas migrated from deeper and hotter parts of the basin.

"My interpretation is that most of northern NPRA and the area west of it, which includes the offshore Burger structure, have been affected by a large amount of gas that flooded this region and displaced the oil that had accumulated there," Houseknecht said.

Specifically, an abundance of gas produced during the Cretaceous Period by deep burial beneath the foothills of the Brooks Range simply flushed northward and displaced oil "that we know had been reservoired in a number of structures in NPRA and is no longer present," he said.

Oil seeps near the northern coast of NPRA lend strong evidence to this hypothesis.

Where Did the Oil Go?

Taking one of the golden rules of geology – to drill where large gas accumulations are known to exist – Houseknecht is replacing

See **Go West**, page 10

Lower Cretaceous, syntectonic breccia of the informally named Confusion Creek conglomerate near the Brooks Range front, south-central North Slope. View to the north.

Go West

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it with a phrase from Manifest Destiny: "Go west, young man."

While the Burger structure looks as promising as areas in NPRA, its oil likely has been flushed from the structure. In contrast, structures farther west – on the west side of the Hanna Trough rift basin – likely did not experience the same gas flush. Cretaceous and Cenozoic strata there are thinner, so it is unlikely source rocks were buried as deep – or heated as hot – as those onshore. In other words, had Shell drilled west of the Burger structure, it might have had better luck.

Geologists who have spent their careers in Alaska agree that Houseknecht's hypothesis is viable.

"During the Tertiary Period, the North Slope tilted and as a result, some oil accumulations spilled toward the west," explained AAPG member Richard Garrard, former exploration manager for ConocoPhillips and exploration director for NordAq Energy, an Alaskan oil and gas company.

"A sweep in the basin will move oil to the periphery of a basin," he said. "And, there are some very large structural, stratigraphic and combination trapping opportunities on that basin's margins."

"Based on the results of Shell's exploratory drilling, one concept to look at for future oil accumulations would be using the displaced oil migration theory and looking for traps along a potential migration fairway that is regionally updip of the Burger well location," added Steve Wright, an AAPG member and a consulting geologist with Alaska Geosciences Unlimited.

"The Hanna Shoal is closer to a source of sands that provide a better opportunity for reservoir development," said April Parsons, AAPG member, former geologist for Statoil and senior exploration geologist with Cobalt International. "You've got to go west to avoid displacement from the tilting as well as erosion of the reservoirs," she said. "However, based on 3-D seismic data I've seen from acreage held by Statoil and Shell, there are pretty good chances of hydrocarbons being discovered, and the west is not the only place with potential.

"The challenge is, there has clearly been multiple episodes of movement with tilting in different directions over time making it much more complex tectonically than the North Slope," Parsons added.

Unable to discuss proprietary information, Parsons – echoing the words of virtually every Alaskan explorer – said that more exploration must be done to unlock the door to the elusive Chukchi Sea.

"We all know the full puzzle is under there," said AAPG member Bob Swenson, retired deputy commissioner of the Alaska DNR and former state geologist for the Alaska Division of Geological and Geophysical Surveys. "Nature put the pieces together. We need to find where she did it."

Well of Knowledge

Since the withdrawal of Shell and Statoil from the Chukchi Sea, negative vibes have been rippling through the industry and chipping away confidence in its potential.

"My company is in the process of raising capital for exploration programs and these things reverberate around the financial communities," Garrard said. "This is not the end of Alaska by any means."

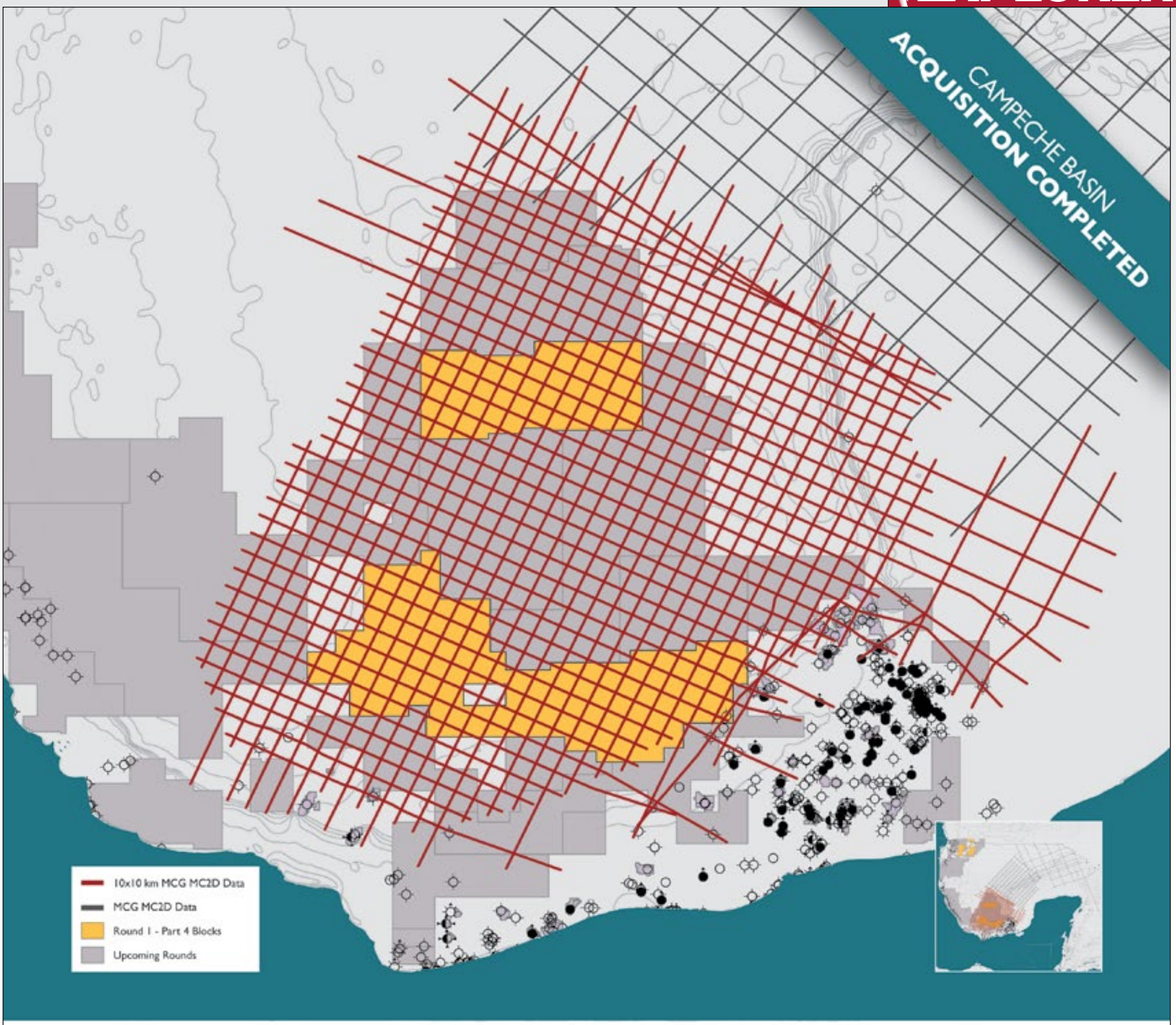
"None of us want to see Alaska offshore condemned based on the results of a few wells," added Wright, referring to the Burger J well and the disastrous Mukluk well drilled by BP in the Beaufort Sea in 1982 – known for being one of the costliest dry holes in history.

But the bottom line is that for every well drilled, the industry gains more knowledge, which locks in a new piece to the Chukchi puzzle.

"We learn by drilling," Myers said. "You have to test, and there is not sufficient testing in that basin yet."

Compared to the Lower 48, the North Slope Basin is highly underexplored – even more so offshore. If one were able to move the Chukchi Sea or offshore NPRA to the Lower 48, "there would be so many exploration wells it would be astounding," Swenson said, explaining that drilling costs and access to infrastructure are substantially lower in the contiguous United States.

See **Alaska Opportunities**, page 12



Alaska Opportunities

from page 10

So, in the game of exploration in Alaska, no well is really drilled in the wrong place, in Swenson's eyes, because each provides additional clues to what lies in the subsurface.

"It's unfortunate that Shell did not encounter what it hoped to find, but that is an inevitable outcome during an exploration program," he said. "But if nobody took those kinds of chances, we wouldn't be where we are today."

"There is potential there. It's a supercharged system. This is wildcat exploration in a geologically complex basin. Keep moving. Keep drilling."

Has the industry forgotten what it took to discover Prudhoe Bay?

"Look at the size of Prudhoe Bay," Swenson said of its 25 billion barrels of oil. "How could you not drill into it?"

Yet, it took nine exploration wells – each roughly 8 inches in diameter – to find North America's largest oil field.

A Sea of Obstacles

Yet, at a time when the price of oil is sinking lower and federal restrictions and mandates on Arctic drilling are growing tighter, most say it's nearly impossible for that young man to move west in search of oil.

"When oil was in the $100 a barrel range, it was a challenge to explore in the Arctic economically," Parsons said. "In today's prices, it is impossible."

In today's economic environment, an enormous accumulation would be required to develop a field and build infrastructure to carry the hydrocarbons to the Trans-Alaska Pipeline System. A huge investment would be needed up front, and the wait time for production would be six to 15 years, Wright surmised.

Until oil prices rebound, some operators are looking at onshore opportunities on the North Slope.

Upper Cretaceous (foreground and mid-background) and Cenozoic (background) strata along the Sagavanirktok River, 65 miles south of Prudhoe Bay. Oil seeps from Cenozoic sandstone near the top of this exposure helped guide the earliest exploration efforts in northern Alaska, contributing to the Prudhoe Bay discovery.

The U.S. Geological Survey has a paper authored by William Craddock and David Houseknecht titled, "Cretaceous-Cenozoic Burial and Exhumation History of the Chukchi Shelf, Offshore Arctic Alaska," published in the January 2016 AAPG BULLETIN.

"With the combination of more 3-D seismic data, advancing production technology, and more aggressive explorers who are willing to take risks, we are seeing signs of new resources on the North Slope," Myers said. "There is more life in state lands than people believed five or 10 years ago."

While offshore exploration is currently off the table, it has not dropped below the horizon, said AAPG member Sandy Phillips, a former senior geoscience adviser with BP Alaska who considers herself "terminally optimistic" about opportunities in Alaska.

Agreeing that the North Slope Basin is highly complicated and highly underexplored, Phillips said those are the very reasons exploration should continue – albeit at a higher price point.

"In no way, shape or form is the industry in a place to condemn an oil play in offshore Alaska," she said. "There is simply not enough data for that."

Although Shell abandoned its Burger J well, it is fighting to extend the duration of its leases in the Chukchi and Beaufort seas. After the federal government denied Shell's request last October, Shell appealed to the Department of the Interior on Dec. 11.

"They may be stopping activities for now," Phillips said, "But they would not be trying to extend their leases if there were no reason to revisit them."

How Much Will Middle East Production Rise?

By DAVID BROWN, EXPLORER Correspondent

For the oil industry, the most worrisome news coming out of the Middle East doesn't involve geopolitics.

It's well known by now that Iran wants to increase production by at least 500,000 barrels of oil per day (b/d) as the lifting of international sanctions allows it to resume crude exports.

But Iran isn't alone.

Kuwait reportedly intends to increase its exploration efforts and is targeting a new offshore oil exploration program within two years. The manager of planning for Kuwait Oil Co. has been quoted as saying the country eventually wants to add a total of 700,000 b/d of oil production.

The United Arab Emirates (UAE) also has plans to add another 500,000 b/d of oil equivalent to its production within two to three years, according to Abdullah Nasser al-Suwaidi of the national oil company Abu Dhabi National Oil Company (ADNOC).

Given the chances for increased production in the Middle East, it's surprising to some that analysts have such a benign outlook for the future of the crude oil market.

That's partly because Iran's oil minister has announced the country is "not seeking to distort the market" and will use caution in increasing exports.

AAPG's Middle East Region.

Balance Restored?

Mainly, though, forecasters are looking at three expectations that will help rebalance crude oil supply and demand:

- Market forces will reduce supply from some areas as oil production becomes uneconomic at today's low crude prices.
- Production will continue to drop from fields already in decline, with heavy investment in enhanced recovery unlikely.
- World demand growth for crude oil consumption will continue to increase over the next two years.

Numbers in projections are slippery by nature, but analysts generally agree on the supply-side calculations. Increased oil production from the Middle East appears to be a certainty. *How much* of an increase is the question.

"The wild card, of course, is Iran. Fairly soon we'll start seeing how much they're going to increase and for just how long," said Paul Tossetti, crude oil markets director for IHS in Dallas.

IHS projects a modest overall increase in Middle East crude output over the next two years, possibly by 600,000 to 800,000 b/d. Tossetti said other countries in the region are unlikely to boost production by much.

"The Kuwaitis have a lot of trouble organizing their oil industry. Qatar is probably on decline for oil production," Tossetti said.

"The only country other than Iran and Iraq on track for raising production is the UAE, but it's going very, very slowly," he added.

Iraq is a special case, where recent increases in production could be stymied by low oil prices.

"Their production over the past couple of years has risen somewhere between 600,000 to 800,000 barrels a day. That's including Kurdistan," Tossetti noted.

But reduced capital expenditures by international oil companies operating in Iraq and the likelihood of further investment reductions make additional big gains unlikely, he said.

On the higher side of estimates, Goldman Sachs began 2016 expecting Middle East oil production to grow more substantially, with Iran, Iraq, Kuwait, Saudi Arabia and the UAE together projected to add almost 1.33 million b/d in crude output.

That increase would be partly offset by production declines in other OPEC countries, especially Nigeria. However, as a result, Goldman Sachs predicted an overall OPEC crude oil production increase of about 812,000 b/d from 2015 to 2017.

See **Oil Production Forecast**, page 16

Left: The National Iranian Oil Co. caption for this image is "Manifestation of self-assurance in Iranian oil industry." The rest of the oil-producing world is presently bracing itself for a flood of Iranian oil following the lifting of sanctions. Photo by Eshagh Rahdari. Right: Kuwait is also expected to ramp up production efforts following its new offshore exploration program. Photo courtesy of the Kuwait Oil Company.

Oil Production Forecast
from page 14

Demand Growth

And worldwide oil production growth will be even less, it forecast, as crude supply begins to decline from North America and non-OPEC Asia.

While Goldman Sachs has been negative on the oil price outlook, and proven correct, it has remained fairly positive on world oil demand growth. Goldman estimates total oil demand to grow to 97.13 million b/d in 2017, a jump of 2.6 million b/d from 2015.

Because demand growth is expected to outstrip supply increases, analysts are looking for a tightening world supply-demand picture to begin as early as the second half of 2016.

Future demand is key because there's already been "substantial growth," Tossetti said. So, you've already got that in your back pocket. That will be pivotal."

A major factor determining crude production growth in the Middle East will be Iran's ability and willingness to increase oil exports. Mohsen Qamsari, director general for international affairs of the National Iranian Oil Company, said the country would adjust output "according to the global market's demand."

"We will exercise great caution to prevent a further decline in international prices and will adopt certain methods and strategies to this end," he added.

Political tensions between Iran and Saudi Arabia earlier in the year caused a very brief flutter upward in oil prices. But the more lasting effect is likely to be negative, according to the Macro Oils service of international consultancy Wood Mackenzie.

"Unless other producers such as Russia, Iran and Iraq agree to reduce their oil production, Saudi Arabia has consistently stated since the November 2014 OPEC meeting, it has no intention of cutting its supply to support oil prices.

"The current ramping up in tensions between Saudi Arabia and Iran only further confirms our view that Saudi Arabia is unlikely to cut its output to help Iran regain market share," it said in a report.

Wood Mackenzie has forecast continued global oil oversupply in the first half of 2016, followed by a drawdown in crude stocks in the second half of the year.

At that time, "with this tightening in the supply and demand balance, political risk will become more important to oil prices," it said.

Today's low oil price environment constrains investment to boost or simply maintain production from the Middle East oil fields currently in decline, analysts note. That has affected Qatar, where one-time plans to push oil production from the prolific Al-Shaheen field above 500,000 b/d appear to have been derailed.

A potential change of operators could affect Al-Shaheen in the near future. Maersk Oil began developing the field in 1992, under a 25-year exploration and production sharing agreement that expires in 2017.

Qatar Petroleum has invited other international oil companies to compete to operate and develop Al-Shaheen, seen as a sign that negotiations to extend the current contract failed. The field, about 50 miles off Qatar's coast, now produces around 300,000 b/d, according to Maersk.

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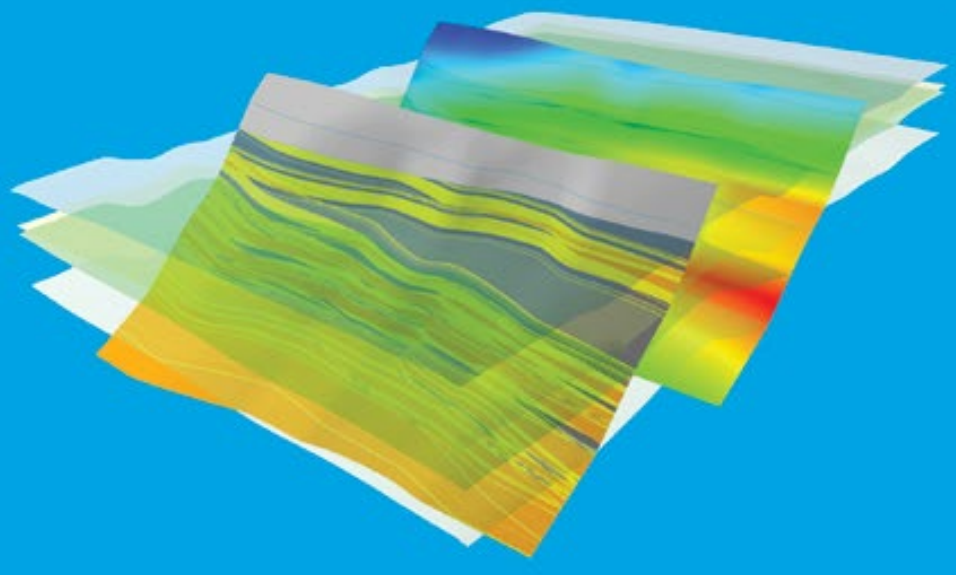

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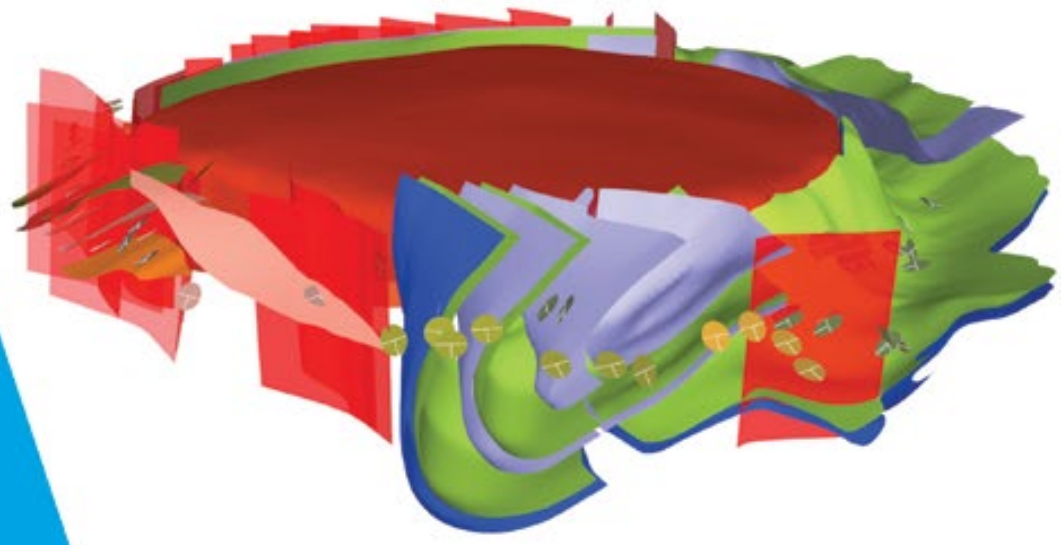

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Saudi Arabia Looks to Unconventionals

By LOUISE S. DURHAM, EXPLORER Correspondent

Owing to the U.S. shale boom, interest and activity in unconventional E&P has spread internationally.

Perhaps the most unexpected locale for these types of plays is the Kingdom of Saudi Arabia.

Given the enormous volumes of conventional production emanating from this hydrocarbon-rich region, it likely surprises many that unconventionals would hold any allure.

During the second EAGE/SPE/AAPG shale gas workshop in Dubai in 2014, a presentation attributed to four authors affiliated with Saudi Aramco reported that an accelerated unconventional exploration program had been launched in Saudi Arabia to develop unconventional hydrocarbon resources in various basins.

The unconventional gas plays evaluated were noted to run the gamut from rich to dry and are located in both the Rub Al-Khali and the Jafurah basins, among others. The targeted calcareous Jurassic sediments are deemed to be some of the richest hydrocarbon source rocks in the world.

Jafurah is east of Ghawar, which is the renowned supergiant oil field discovered in 1948. Accounting for more than half of Saudi Arabia's cumulative oil production, the field also kicks out impressive volumes of gas.

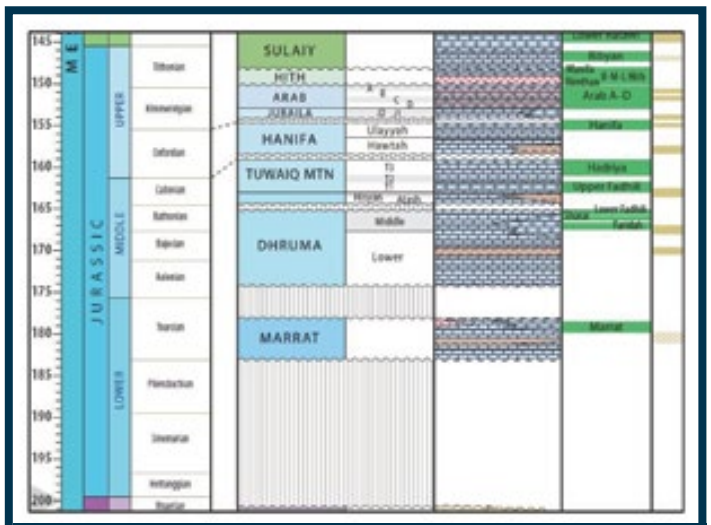
It has long been recognized as the world's largest conventional oil field, stretching 174 miles in length and 16 miles across to encompass 1.3 million acres.

The Jurassic-age Arab formation is a major oil reservoir in the Middle East, and the reservoir rock at Ghawar is the Jurassic Arab-D limestone having exceptional porosity. The Arab-D here includes the lowermost zone of the Arab and the uppermost zone of the Jubaila formation.

Some find it intriguing that the now-famous Cretaceous-age Eagle Ford shale in South Texas is a close analog to the Jurassic shale system in Saudi Arabia. For instance, the Jafurah and South Texas basins where the shales were deposited are both locally deprived of siliciclastic content and contain kerogen-rich, carbonate mudstone facies.

Jurassic carbonate reservoirs received vast amounts of oil from Jurassic carbonate source rocks within the Jurassic Tuwaiq Mountain, Hanifa and basal Jubaila formations, according to AAPG member Robert Lindsay, geological technical services at Saudi Aramco (retired), and his former colleagues. He has spoken on the topic at various meetings, including AAPG ACE 2015 in Denver.

The Jurassic source rocks contain 1-14 percent TOC, plentiful organopores and clay content quantity ranging from very low to none, according to Lindsay and his colleagues.



Jurassic Strata is the source of 70 percent of Saudi Arabian oil.

LINDSAY

Robert Lindsay is senior author of the presentation, "Jurassic Unconventional Carbonate Source Rocks, Saudi Arabia," which will be presented at the 12th Middle East Geosciences Conference and Exhibition (GEO 2016) in the Kingdom of Bahrain, March 7-10.

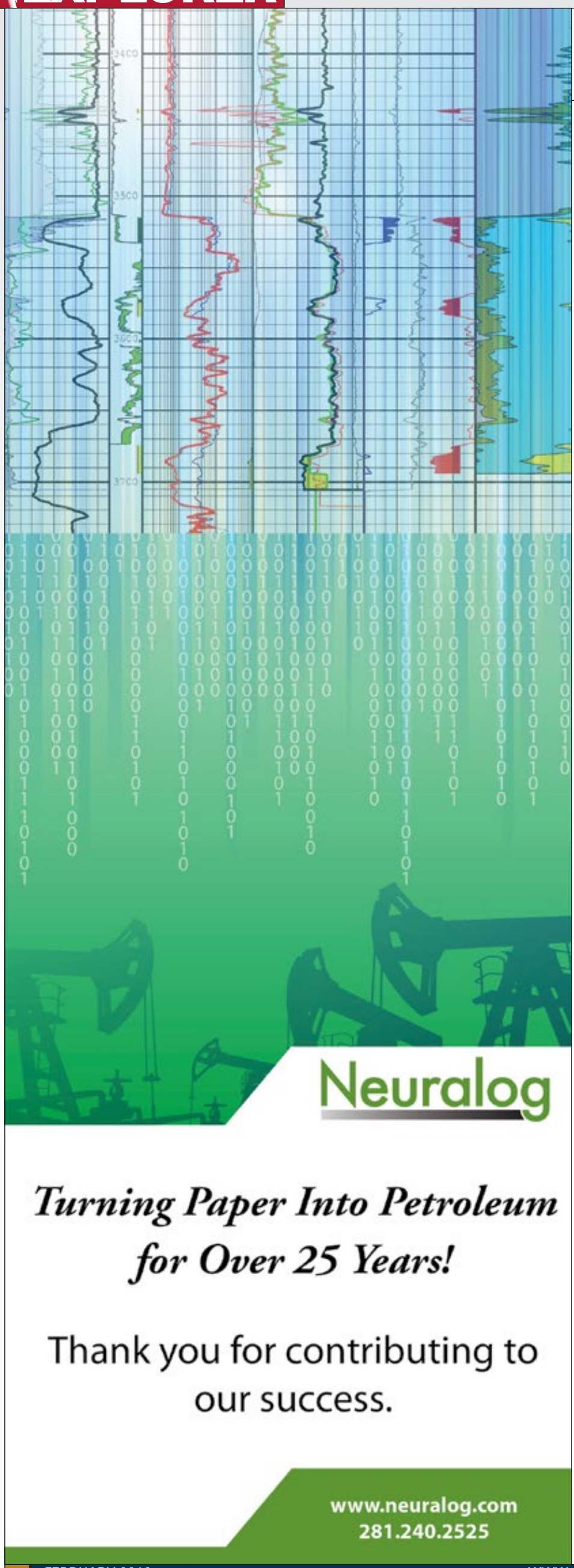
Jurassic unconventional carbonate source rocks, Saudi Arabia. The outline of the shelf to basin transition for the Tuwaiq Mountain and Hanifa formations. The position of the Jafurah Basin is in the center of these basinal settings.

Deposition was in an outer ramp to basin depositions environment, beneath fair-weather wave base and within storm wave base.

He noted that a pycnocline, or the area where the density changes rapidly with depth, divided the water column into:

- Anoxic water beneath.
- Dysoxic water at the contact.

See **Source Rocks**, page 20



Industry, Academia Improve Ties in the Middle East

By KRISTI EATON, EXPLORER Correspondent

Collaborative relationships between the petroleum industry and academia have been steadily improving in the Middle East over the years, but there is still much room for improvement, according to a moderator at a panel examining the issue at the upcoming GEO 2016 conference.


ABDUL-BAQI

The conference, which is scheduled for March 7-10, will showcase oil and gas exploration technology and services in the Middle East.

One of the panels will examine the relationship between the petroleum industry and academia.

Historically, there has been no relationship between universities in the Middle East and the oil and gas companies that operate there, according to one of the moderators at the panel, AAPG Honorary member and chair of the Arabian Geophysical and Surveying Company (ARGAS), Mahmoud M. Abdul-Baqi.

But, he said, newer universities in recent years have worked to change that by creating and developing collaborations with industry.

"It hasn't been a very strong relationship, but at least there has been one," he said, adding that he would like to see the relationships strengthen and improve.

Mutual Benefit

There are several benefits to such relationships, Abdul-Baqi noted. New university graduates have potential job leads, schools may be able to receive donated items from companies, and training and visiting lecture series can help spur innovation.

"We are hoping that the improvements keep happening, accelerating the pace further and faster," said Abdul-Baqi, who has been active in professional societies and traveling around the region in addition to his years at ARGAS.

He said he doesn't believe there are any unique obstacles or issues specific to the Middle East that make collaboration between industry and academia more difficult; it's simply getting people from both sides interested and invested.

According to conference organizers, strong collaboration between E&P and educational institutions is affected by three factors: data access, innovation space and implementation.

Without strong collaboration between industry and schools, accessing critical data to develop policies and procedures is difficult.

Models of Collaboration

Panelists at the session will include industry and academic representatives from the French Institute of Petroleum, Abu Dhabi Petroleum Institute, King Fahd University of Petroleum and Minerals and others.

Abdul-Baqi said the French Institute of Petroleum is an example of a positive collaboration. The school offers master's level and doctoral programs with more than 13,000 alumni in more than 100 countries.

There are 40 permanent professors and 350 instructors from the industry. More than 50 companies support the school through scholarships, apprenticeships and study leave for professionals.

Another recent effort underway to bridge the gap between the geoscience education field and professional field is the NERC Centre for Doctoral Training at Heriot-Watt University in the United Kingdom.

Several companies, including BG, BP, Shell and ConocoPhillips, are supporting a 20-week training academy.

It began in October 2014 and focuses on four areas: environmental impact and regulation; extending the life of mature basins; exploration in challenging environments; and unconventional oil and gas resources. The first set of doctoral students is set to graduate in 2018.

Source Rocks

from page 18

- Oxygenated water above.

He provided an outline of the Jafurah Basin unconventional lithofacies types occurring in order from shallow to deep:

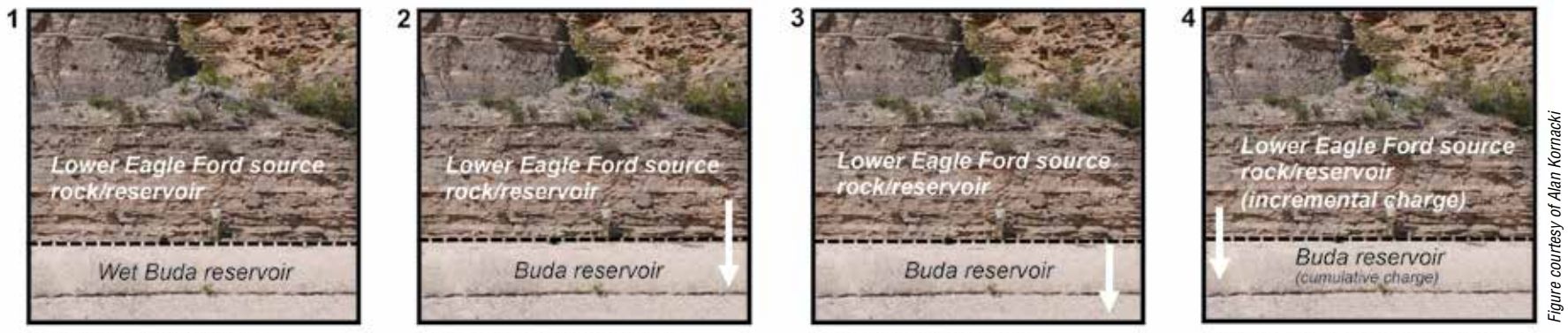
- Evaporite strata – hypersaline.
- Bioturbated shallow marine strata – oxic.
- Bioturbated deep marine strata – oxic.
- Horizontally bioturbated deep marine strata – dysoxic.
- Laminated with starved ripples – anoxic.
- Laminated without apparent ripples – anoxic.
- Massive appearing very thin to thin- bedded strata – anoxic.

Additionally, Lindsay summarized the conclusions reached by the Jurassic source rocks study:

- A new play in Jurassic carbonate source rocks (in Jafurah).
- Source rocks filled Arab-D supergiant oil fields (such as Ghawar, Shaybah, Abqaiq, among others).
- Gas play is the size of Eagle Ford play in North America.
- Depositional model has been created connecting conventional and unconventional plays.
- Key lithofacies have been identified and tied to the depositional environment.
- Storms swept the ramp margin/ basin and delivered TOC concentrated in fecal pellets into the basin.
- Porosity and permeability are elevated compared to the Eagle Ford.

If you're hoping to be privy to the end results about this new play in the Jafurah Basin, patience is key.

"It's still in appraisal mode," Lindsay said.



Lower Eagle Ford source rock generates/retains low-maturity oil.

Eagle Ford expels low-maturity oil into fractured Buda reservoir.

Eagle Ford kerogen generates higher-maturity oil, expelling low-maturity oil it had retained.

Eagle Ford expels some higher-maturity oil into Buda, which mixes with the low-maturity oil.

Figure courtesy of Alan Kornacki

The Eagle Ford and the underlying Buda formations illustrate one of the mechanisms by which oils from adjacent unconventional reservoirs can have different fingerprints. Although oils in both reservoirs were sourced by the Eagle Ford, the two reservoirs contain different oils since one reservoir contains an "incremental" oil charge while the other contains a "cumulative" oil charge.

Unconventional reservoir development

'Oil Fingerprinting' Has Wide Application

By LOUISE S. DURHAM, EXPLORER Correspondent

Recovering the remaining oil in the subsurface is a basic common goal of producers and geoscientists.

To accomplish this, they must first identify the location of what is left to recover.

This effort can be especially challenging when dealing with unconventional reservoirs, where hydraulic fracturing and commingled production from differing horizons/formations are often the norm.

Enter "oil fingerprinting," where geochemical differences between oil samples produced from different formations or zones can be used as natural tracers to quantify the contribution of each reservoir to a commingled production stream, explained AAPG member Mark McCaffrey, geoscience manager of interpretive services at Weatherford Laboratories in Dallas.

"The average black oil has more than 100,000 different compounds, and we measure about a thousand of them," McCaffrey said. "Two different oils could be 99-percent similar in composition and still have 50 differences, so you can easily tell one oil from another – it's like a fingerprint."

This low cost oil "fingerprinting" method has long been used to geochemically allocate commingled production from conventional reservoirs.

It also has key applications for unconventional reservoir development.

Characterizing fracture height, for example, is a big deal.

An operator can determine if hydraulically-induced fractures have propagated out of the formation containing a lateral wellbore and into an overlying or underlying pay zone, resulting in commingling of oil produced from different reservoirs. In other words, determine if the fracture(s) outgrew its anticipated length.

Oil fingerprinting enables the operator to define what percentage of production is being sourced from each zone contacted by the induced fractures. This information, in turn, impacts the strategy for developing each of the horizons in the prospect.

In some instances, this quantitative allocation of individual pay zones to the commingled production stream is needed for royalty/tax calculations.

McCAFFREY

AAPG member Mark McCaffrey, geoscience manager of interpretive services at Weatherford Laboratories, presented this information in his lecture "Three Key Applications of Oil Fingerprinting to Unconventional Reservoirs: Characterizing Fracture Heights; Allocating Commingled Production; and Identifying 'Cross Talk' Between Horizontal Wells" at Unconventionals Update, an AAPG Geosciences Technology Workshop recently held in Austin, Texas.

Identifying Cross-Talk

Then there's the issue of identifying "cross-talk," where induced fracture networks from separate wells completed in adjacent formations hook up with each other. This can occur when one well is drilled nearby another with each completed in a different formation, based on the belief that the fractures in the second well won't be long enough to tie in with the fractures from the first.

The geochemistry of the oils produced from the two wells will indicate if "cross-talk" is occurring.

So, you ask, if you don't want to deal with unanticipated occurrences like fracture system hookups and such, why not just space the wells a bit farther apart?

This may sound like a no-brainer, but there are other considerations that go into that decision.

For starters, operators like to drill wells close together for a number of reasons, both practical and financial.

Then there's the likely fallout from retracting an announced plan to drill, say, 500 wells in a certain play over the course of the coming year. Suddenly declaring that the plan has been scaled back by half would have repercussions best avoided.

Oil fingerprinting can be used to decide if increased spacing is truly needed.

How It's Done

Overall, oil fingerprinting follows a somewhat simple blueprint.

The procedure begins with dead oil samples collected at the earth's surface using glass jars with Teflon-lined lids. The dead oil is evaluated using high-resolution gas chromatography (HRGC) to determine the abundance of the different compounds. Between 200 and 250 natural tracers are typically identified during an oil fingerprinting project, said McCaffrey.

"A key challenge in each project is the need to have a sample of oil that is certain to come from each zone," he said. "These single zone pure oils are called end-member samples, and there are some great strategies the operator can use to collect these samples, which we use to calibrate each project.

"The relative contribution of each end-member oil sample to a commingled sample is calculated using a linear-algebra solution of simultaneous equations, where the number of equations equals the number of natural tracers," he noted. "The accuracy of an allocation estimate is very high."

He emphasized also that geochemical production allocation is dramatically less expensive than production logging and can be used in situations where production logging cannot be applied. For example, it can't be used to assess the fracture height given that the logging tool cannot traverse upward through the fracture.

The relative low cost for the geochemical methodology allows field engineers to monitor output frequently over lengthy time periods. This enables the operator to stay on top of the individual zones' changing contribution to the production stream.

Photo courtesy of Weatherford Laboratories

The different compositions of these oil samples cause them to have different appearances. Even two oils that appear very similar may have thousands of chemical differences, causing oils from different reservoirs to have unique "fingerprints."

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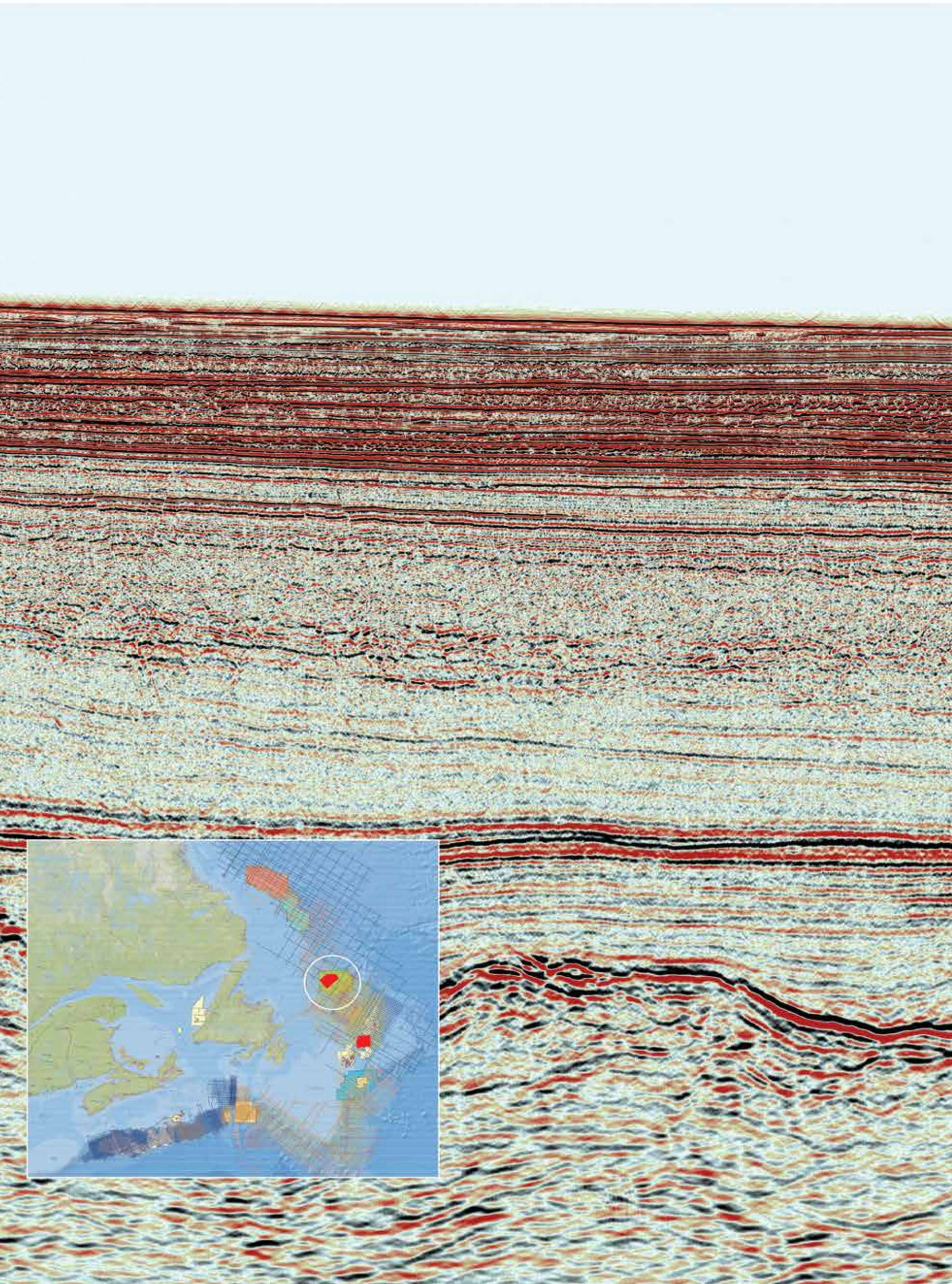

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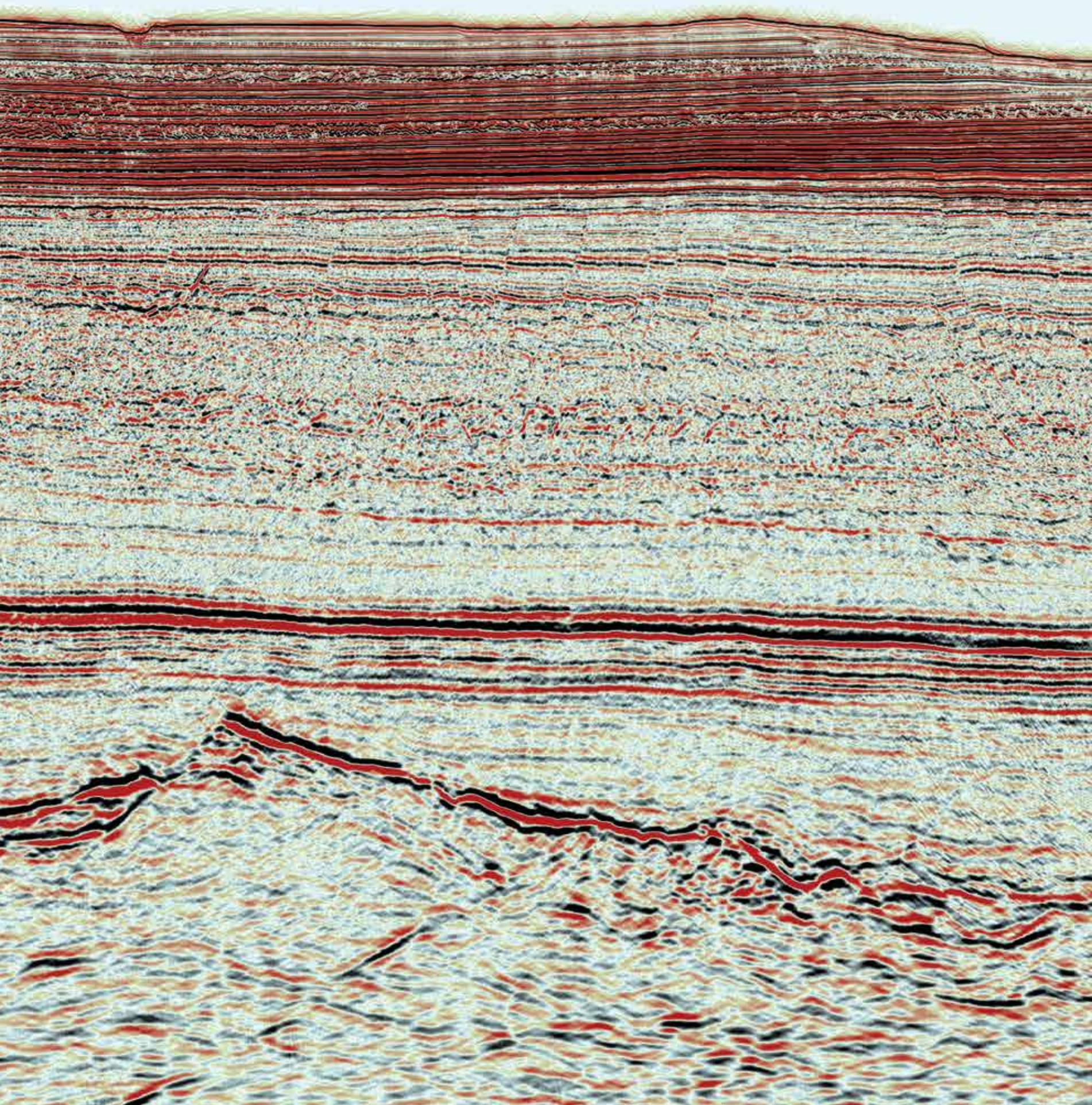

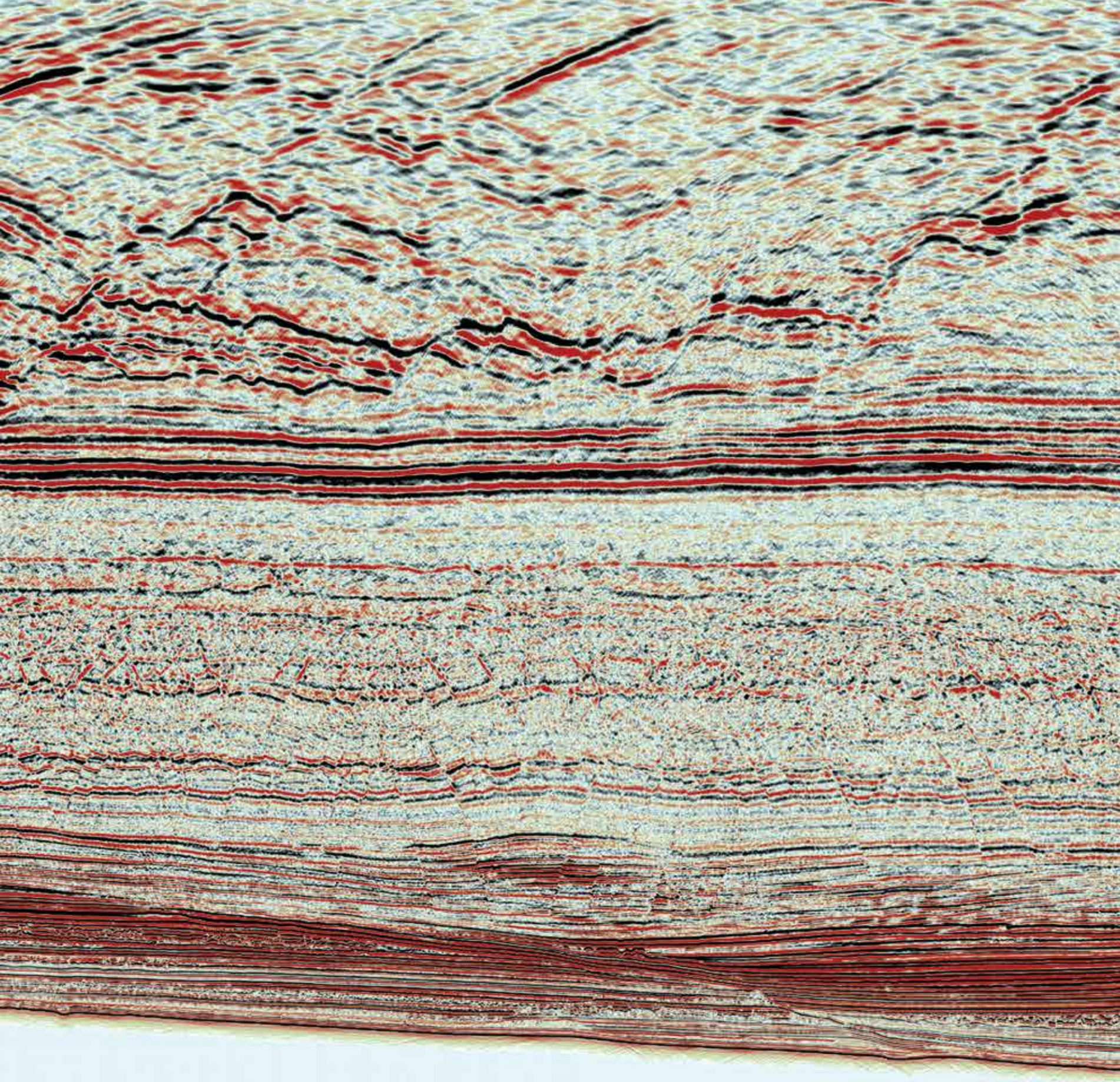

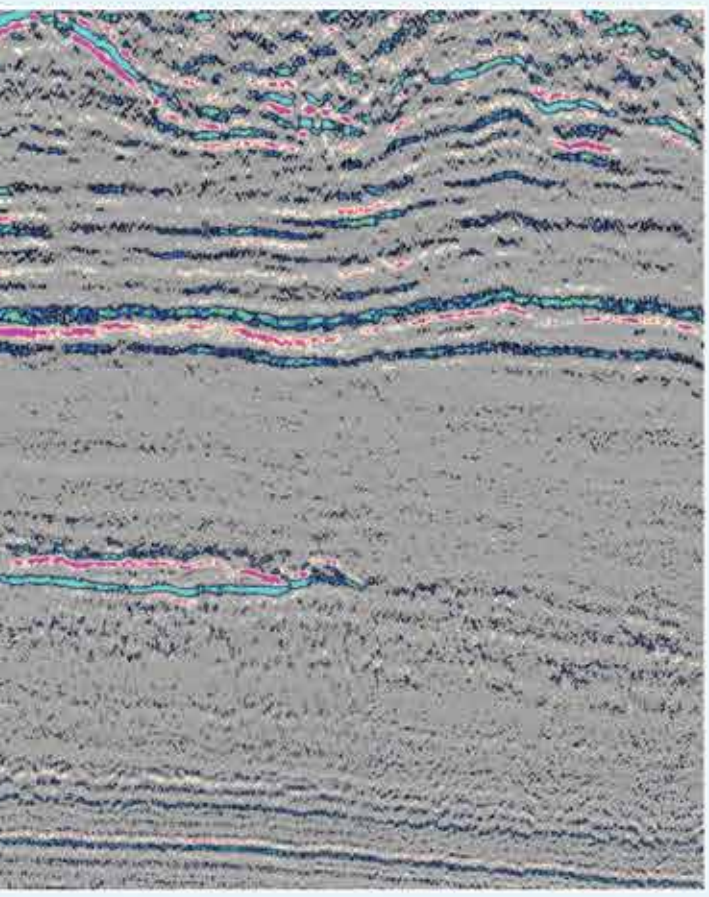

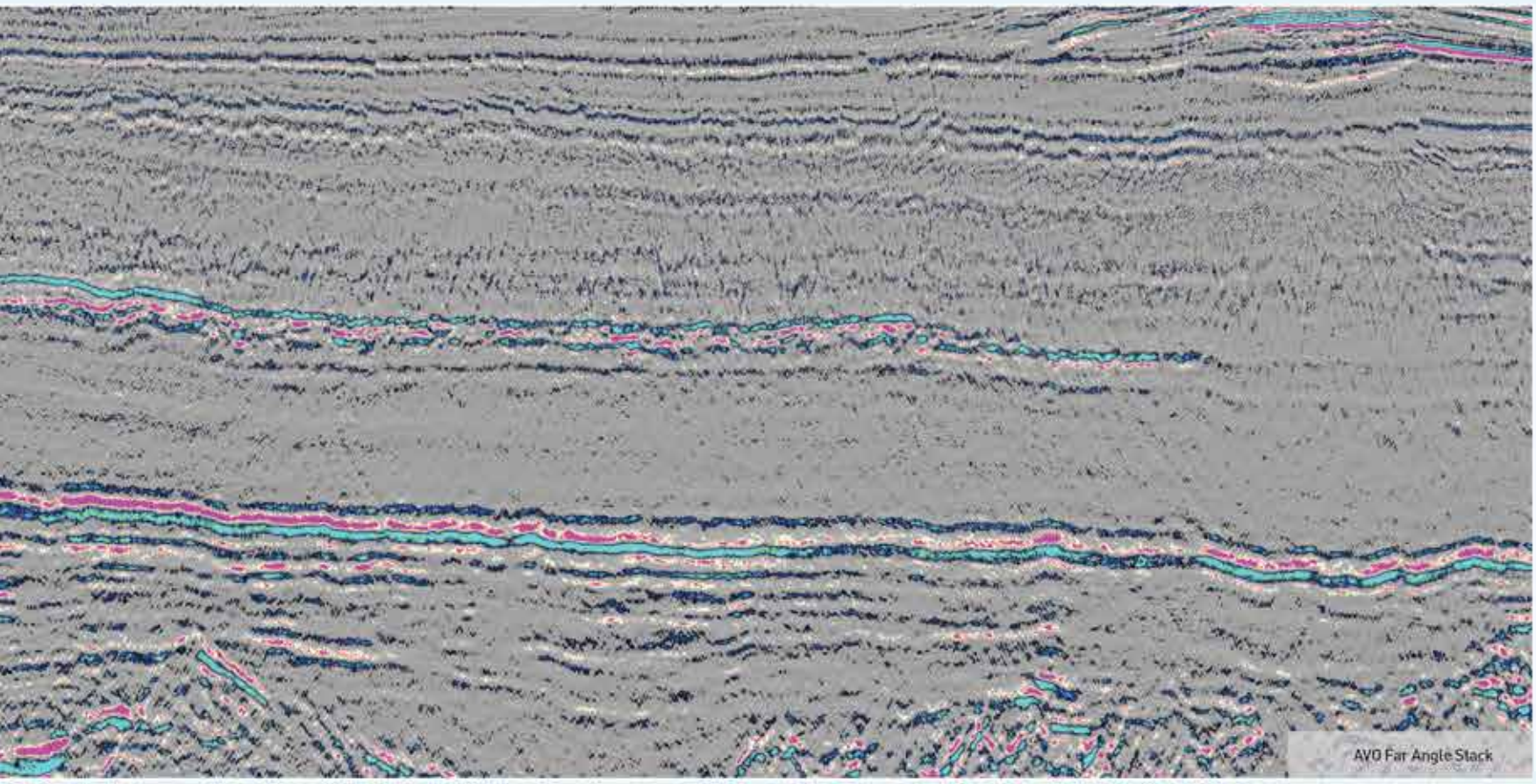

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GEO 2016 highlights

Today's Geosciences, Tomorrow's Energy

By EMILY SMITH LLINÁS, EXPLORER Correspondent

In the midst of regional geopolitical tensions and plunging oil prices worldwide, negative headlines from the Middle East aren't hard to find. But, geoscientists and industry professionals know that the region has plenty of good news as well.

A bright spot for the region and the energy sector alike is GEO 2016, the 12th Middle East Geosciences Conference and Exhibition taking place March 7-10 in Bahrain.

The event, organized by AAPG, EAGE and SEG serves as a model of collaboration at a time when interdisciplinary work environments and tightened company budgets make cooperative efforts between professional societies more important than ever.

GEO 2016, titled "Today's Geosciences, Tomorrow's Energy," is supported by all six national oil companies in the Gulf Cooperation Council as well as local geoscience societies from Bahrain, Qatar, Kuwait, the United Arab Emirates, Oman and Saudi Arabia.

For AAPG member Pinar Yilmaz, lead for external upstream projects at ExxonMobil Exploration Company and member of the GEO technical program committee since 1998, the collaboration between national and independent oil companies and professional societies creates a dynamic program that draws repeat attenders.

The 12th Middle East Geosciences Conference and Exhibition will be held in the city of Manama, Bahrain. Photo by Wadiia.

"GEO conference is the center of excellence for Middle East geosciences where you network with the decision makers, experts and colleagues working in the Middle East oil and gas industry," she said.

"Field trips to Oman are always the highlight of the conference, as well as special field trips to Saudi Arabia and Emirates for ancient and modern carbonates representing giant reservoirs," she said.

Robert Kuchinski, president of AAPG's Middle East Region and senior technical adviser for formation evaluation in the Middle East/Africa Region for Weatherford, is planning to attend GEO for the fifth time.

He describes GEO as "the premier geoscience conference in the region" and said the event offers numerous benefits to attendees.

"The technical program is rich and varied. It is a good place to meet geoscientists working in the Middle East and to expand your knowledge on Middle East geosciences and the Middle East oil and gas Industry," he said.

Record Attendance

Conference organizers are not the only ones excited about GEO. At a time when energy sector events throughout the world are facing lower-than-usual attendance, GEO registration is ahead of where it was prior to the last event, held in 2014. The technical program committee received a record number of abstracts – 200 more than in previous years.

Aiman Bakhorji, technical program committee co-chair from Saudi Aramco, said GEO is renowned as an outstanding platform where new and exciting avenues for learning and growth can continually be found.

"This year, 2016 will be no different," he said, adding that the conference will be geared to address to current industry conditions.

"With the current low global oil prices and the associated future challenges that the industry will confront, limited

See **Technical Program**, page 28

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Technical Program

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opportunities will arise to bring together a wide range of technical expertise, and to empower our professionals to meet these challenges head-on," Bakhorji said.

"GEO 2016 will provide such a unique opportunity and will be an important source of knowledge-sharing and new technology developments coupled with extensive networking opportunities."

The final technical program will include 220 oral presentations, more than 150 posters, short courses and Middle East region-specific field trips. The conference also will include five panel sessions:

- Long Term Strategies Through Unpredictable Markets.
- IT Emerging Trends.
- Integrated Technologies for Better Performance.
- Unconventional Resources of the Middle East.
- Industry-Academia Engagement and Collaboration.

New GEO events include a CEO panel session featuring executives from ADCO, Aramco and Schlumberger, and a special session, "Women's Growing Role in the Energy Industry," led by top female industry professionals.

Tomorrow's Energy

GEO's focus on the future also includes a robust program for young professionals and students representing 18 universities.

In addition to networking events, technical courses, poster sessions and core workshops, the conference features a soft skills short course and a panel session discussing factors for success in the industry.

AAPG's Imperial Barrel Award competition, scheduled for March 6, will include eight teams – a record number for the Middle East Region.

University students can participate in the EAGE GEO Quiz and the SEG Challenge Bowl during the week, and 200 high school students are invited to tour the exhibition.

Kuchinski said he looks forward to learning about "Tomorrows Energy" at the conference.

"We expect this energy will be discovered and produced using ideas and technologies that are new and/or haven't been thought of or invented yet. It will cover the range from new conventional discoveries, bypassed pay, EOR, unconventional resources and things we may not know about yet," he said.

Kuchinski said he expects participation from throughout the region and the world, noting that energy professionals from abroad have much to learn from their colleagues in the region.

"The Middle East contains the world's largest oil and gas reservoirs distributed throughout many unique, interesting and dynamic countries," he said."

These oil and gas deposits are being developed by NOCs that are committed to producing as much oil and gas as they can, using the most advanced technology and sophisticated techniques possible.

"As much of this technology and techniques are adapted from other parts of the world, a geoscientist in the Middle East gets exposure and learning opportunities from people all over the world," he said, "and also has the chance to explore many exciting and well-exposed outcrops.

"Thanks to the arid climate and lack of vegetation, there are numerous outstanding geological sections to visit and study," Kuchinski said.

Bakhorji agreed that attending GEO 2016 is an invaluable investment for energy professionals everywhere.

"As always, GEO 2016 will be attended by decision makers, senior executives and top notch scientists and engineers from across the industry providing international networking and educational opportunities that will enrich our career and professional development. This will indeed be the most productive and strategic time that one can spend away from his office in 2016," he said.

Event details, registration, sponsorship and exhibition opportunities are available at http://geo2016.com.

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AAPG Education

What Does the Future Geologist Look Like?

By MATT BOYCE, Gulf Coast Section Young Professional

A popular topic among educators and recruiters in our discipline is what geology, and the people who practice it, will look like in the future.

It's an interesting question when you consider the origins of our discipline, its pioneers and how both geology and its practitioners have evolved in the past 100 years.

Arguably, one of the most important contributors to our field was James Hutton. He was known as "The Man Who Found Time," but not because he made a deliberate effort to do so. Hutton was attempting to solve the riddle of erosion and sedimentation – a quandary that had plagued many naturalists and thinkers of the day.

When he "found" time, he was hardly aware that he was laying the foundations of geology.

Hutton's concepts were furthered by Sir Charles Lyell. Lyell's main vocation, by all accounts, was law, yet he authored one of the most widely used and interesting books on geologic theory at the time.

So influential was Lyell's "Principles of Geology" that it was carried by his friend Charles Darwin aboard the H.M.S. Beagle and heavily informed the theories put forth in "On the Origin of Species."


BOYCE

> The historical precedent of geology as an integrative science is well-established and the geologists of the future will need to be equally multidisciplinary.

You're Only Right For So Long

Lyell's contributions evolved the definition of a modern geologist by popularizing Hutton's theories of uniformitarianism. He rejected the prevailing theory of deposition by catastrophism and cemented sedimentation and erosion as basic geologic principles.

The result illustrates one of the beautifully ironic truths of our science: as my graduate adviser observed, "In geology, you're only right for so long."

Our understanding of the earth and its history is being continually refined by advances in research and technology.

Consider William "Strata" Smith, creator of the first geologic map of Great Britain. During the early 1800s, Smith conducted stratigraphic surveys on foot, on horseback and other means of transportation. In doing so, he inadvertently evolved our science to rely on extensive amounts of field mapping.

Nearly 200 years later, and despite the advent of remote sensing, mapping remains a staple of geologic training. If Smith had access to Google Earth by some odd change of fate, it is unlikely that mapping intensely by foot would be a staple in our education.

However, even with Google, the mapper is no better off in understanding the subsurface. Mapping technology may have evolved beyond the methods employed by Smith, but the philosophy of "ground truthing" he pioneered remains fundamental.

The historical precedent of geology as an integrative science is well-established and the geologists of the future will need to be equally multidisciplinary. The transition to this future reality already can be observed as the title of "geologist" is supplanted by "geoscientist" on many business cards and email signature lines.

Increased emphasis on math and physics will be required as techniques for extracting hydrocarbons from rock become increasingly complex.

For example, in the past 15 years and since the boom of unconventional plays, we have begun to produce hydrocarbons from nano-pores, which was unthinkable 20 years ago and akin to the denial of uniformitarianism in Hutton's day.

This achievement evolved from past endeavors to understand flow through macro-pores.

Perhaps future geoscientists, with a greater proclivity for physics, will tackle the issue of hydrocarbon flow through pico-pores and change how we look at producible stratigraphic horizons.

More Math and Physics

I have been told by many that geology will ultimately begin to merge more with engineering, but I passionately disagree.

Much of the engineering we deal with in industry is related to mechanical and physical properties. Currently, the most pressing problem for a geoscientist is not how to produce hydrocarbon, but how to find more of it that will produce similarly.

My opinion is that sometime in the future, as the industry encounters more technical challenges, you will likely see additional math and physics courses in most geologic curriculums and new hire geoscientists with multiple, potentially unusual, skill sets. You likely will see less reliance on the previous "standards" of education in geology and more emphasis on using computer-based technology to rapidly find and produce new reservoirs.

If Hutton, Lyell and Smith are any indication, the geoscientist of the future will be an out-of-the-box, integrated thinker that will push the industry forward, and the rest of us along with it.

INDUSTRY HIGHLIGHTS

Schlumberger, Statoil To Conduct Multiclient WAZ Survey in the Campeche Basin

Schlumberger announced that Statoil Gulf of Mexico LLC has signed an agreement to license a large part of the WesternGeco Campeche wide-azimuth (WAZ) deepwater multiclient seismic survey in the southern Gulf of Mexico. The license also includes collaboration with WesternGeco in the seismic processing phase.

"We are pleased to have the opportunity to collaborate with Statoil in this breakthrough project, which is the first WAZ multiclient broadband survey in Mexican waters of the Gulf of Mexico," said Maurice Nessim, president, WesternGeco. "The complexity of the geology in the Campeche requires wide-azimuth acquisition to image the subsalt effectively, and we are bringing all of our experience gained in the US Gulf of Mexico to deliver enhanced subsalt imaging to our clients."

A fleet of eight vessels is conducting the survey in the Bay of Campeche for the three-year project. The project follows the Mexican government opening licensing rounds to non-government companies for the first time.

For further information about the Schlumberger multiclient surveys, visit www.multiclient.slb.com/mexico.

OpendTect Pro Launches

Oil companies will be able to enhance profit and reduce costs with dGB Earth Sciences "OpendTect Pro." This unique seismic interpretation system is more accurate and less expensive than all competitive systems currently available on the market. With low oil prices and oil companies looking to save costs OpendTect Pro is the perfect answer.

"OpendTect, our flagship product, is used by thousands. We are proud to serve open source users, academic users, and commercial users from across the globe. OpendTect is used for data visualization and attribute analysis or as a platform to run special workflows supported in commercial plugins. Although basic interpretation tools have been available for a long time, OpendTect has never been targeted as a competitive seismic interpretation system," said Paul de Groot, dGB's president and co-founder.

The new release also marks the launch of a new commercial plugin by dGB Earth Sciences. The Faults & Fractures plugin offers new fault attributes and edge-preserving smoothing filters, as well as tools for extracting fault planes and un-faulting seismic volumes.

Finally, dGB is implementing a new 3-D HorizonCube algorithm also based on CSM algorithms. Instead of tracking the dip-field as with the current HorizonCube tracker, the new algorithm provides a constrained inversion of the dip field with any errors globally minimized. Constraints are in the form of user-picked positions on multiple seismic events. You can also use conventionally tracked horizons and well markers as constraints.

Visit www.dgbes.com for more information.

Baker Hughes Begins Field Trial of LEAP Adaptive Production System

Baker Hughes announced that the first field trial of its "LEAP" adaptive production system, installed in December at a depth of 5,200 feet in the Mississippi Lime play in Woods County, Okla., for SandRidge Energy, is delivering 300-percent greater oil production and 200-percent higher natural gas production compared to the previous artificial lift solution. In continuous operation since its installation, the system was seamlessly deployed through the deviated section of the wellbore and started on its first attempt with no issues.

An entirely new approach to artificial lift, the LEAP system is designed to adapt to the dynamic production profiles typical in most unconventional oil wells.

"Until now, operators have had to use 100-year-old technology that was never intended to operate in deep, horizontal wells or to handle the rapidly declining production rates and high gas volumes typical of unconventional reservoirs," said Wade Welborn, vice president of artificial lift systems at Baker Hughes. "As the first artificial lift technology designed specifically for these unique production challenges, the LEAP adaptive production system represents a step-change in artificial lift technology."

The downhole system consists of a positive displacement pump, which can be installed to sit deeper in a well than traditional rod pumps, a submersible linear electromagnetically actuated motor, which drives the pump and eliminates the need for the long rod string (a primary source of failure in rod lift systems) and a sensor which provides pressure and temperature data to help ensure the highest level of production optimization and system longevity. Unlike any other positive displacement pumping technology currently available, proprietary software built into the LEAP system surface variable speed drive (VSD) integrates with downhole electronics to allow remote adjustments to the pumping system speed and stroke length as production rates change.

"Overcoming the technical hurdles associated with unconventional production isn't the only advantage of the LEAP system. It also is helping Baker Hughes meet its commitment to deliver solutions that continually improve the safety

For more information, visit www.bakerhughes.com.

IN MEMORY

AAPG member William R. Dickinson has passed away.

Dickinson was renowned as a leader in the "plate tectonics revolution," as well as for his work in sedimentary geology and Pacific Oceana geology.


DICKINSON

He was professor emeritus at the University of Arizona and a member of the U.S. National Academy of Sciences.

He was an AAPG member since 1975 and has been honored with numerous awards throughout his distinguished career, including AAPG's A.I. Levorsen Memorial Award.

He resided in Tuscon, Ariz., but passed away in his sleep while he was on an archeological trip to Nuku'alofa, Tonga on July 21, 2015. He was 83.

Johnnie Boyd Brown, 77
Midland, Texas, Feb. 10, 2015

Keith Allen Lowell, 87
West Vancouver, Canada, July 17, 2015

Rodney Rymer, 58
Opelousas, La., Aug. 28, 2015

Lew Gilliam Schroeder, 86
Huntington Beach, Calif., Oct. 27, 2015

Rudolf B. Siegert, 81
Mobile, Ala., Oct. 14, 2015

Joseph Bernard Teichman, 81
Hallandale, Fla., Feb. 22, 2012

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

Spain's Oldest and Only Onshore Oilfield

By JORGE NAVARRO COMET

The Ayoluengo field was the first commercial oil discovery in Spain and more than 50 years later remains the only onshore oilfield in the Iberian Peninsula.

The field was discovered in 1964 and is still producing. It is located about 300 kilometers north of Madrid in the southern part of the Basque-Cantabrian Basin, a geological region where natural oil seeps, tar sands and asphalt have been recognized in outcrops since the early 20th century. This region was considered highly promising and most of the hydrocarbon exploration efforts in Spain during the 1940s and 1950s were focused here.

The Compañía Arrendataria del Monopolio de Petróleos Sociedad Anonima (CAMPSA), the Spanish-government petroleum monopoly created in 1927, was in 1946 granted the hydrocarbon exploration rights for a 2,800 square-kilometer area north of Burgos. With light rigs, CAMPSA drilled some shallow stratigraphic wells, all based on surface geological surveys, as no reflection seismic was available then, resulting in many of the outcropping anticlines being pierced.

Later exploration by CAMPSA was focused in the Zamanzas Valley, along the eroded axis of a large surface anticline with outcropping Cretaceous tar sands in its core. The shallow wells typically found heavy black oil while drilling the Cretaceous section; traces of gas and very small amounts of lighter oil (26-28 degree API) along with salt water were occasionally recovered from the Jurassic carbonates, but no commercial flow was established.

Additionally, during the 1940s, rudimentary and experimental underground mining in the Zamanzas Valley was carried out by CAMPSA to exploit the tar sands – a process that was quite primitive. The tar sands were crumbled and dumped into large water tanks heated by wood fire.

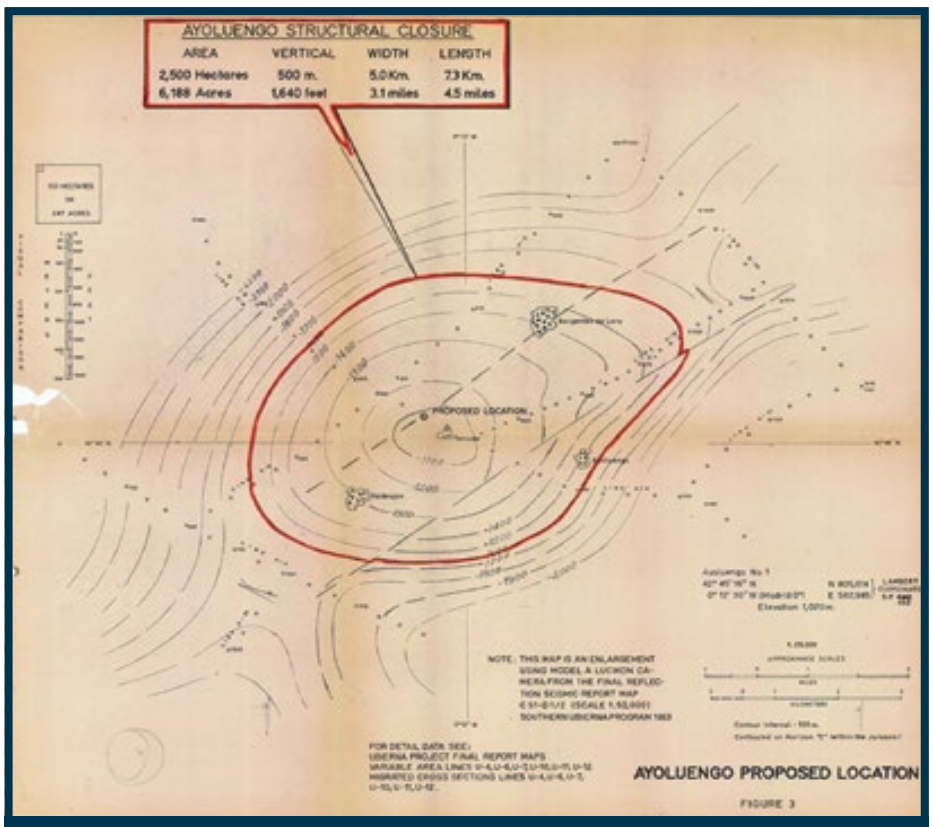
Heat favored separation of the bituminous material that floated on the surface and then was manually collected with dippers and poured into barrels. Oil production was marginal – only about one to three barrels per day. Eventually, this exploitation was abandoned because of the uneven distribution of the tar impregnations and the poor economic returns.

After the Spanish Civil War (1936-39), the country faced economic sanctions from the international community. Economic isolation combined with nationalist rhetoric committed the Franco dictatorial regime to pursue self-sufficiency. By the late 1950s, the failure in self-sufficiency planning seemed clear and the regime began modifying economic policy and lowering restrictions to foreign investment.

In December 1958, a new hydrocarbon law was enacted for petroleum exploration and production that sought to encourage foreign companies to explore. As a result, most of the promising Spanish basins were covered with exploration licenses. It allowed companies with as much as 100-percent foreign capital to work in Spain, while favoring the association of national and foreign companies for the exploration of state reserves, with the state keeping a majority of the share.

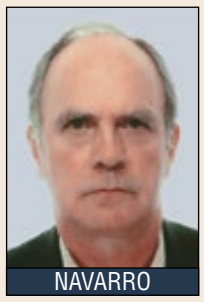
In 1959, CAMPSA signed an agreement with American Overseas Petroleum Limited whereby CAMPSA assigned a 50-percent interest in their exploration permits: 25 percent went to Standard Oil Company of California (which later became Chevron) and 25 percent to Texaco. In 1960, the company named Amospain (CAMPSA 50 percent, California Oil Company of Spain 25 percent, and Texaco Spain Inc. 25 percent) was awarded the operatorship of the Ubierna Exploration Permit, located within the former state national reserve north of Burgos, previously held by CAMPSA.

Geological map of the Iberian Peninsula showing the Ayoluengo oil field location, about 300 kilometers north of the city of Madrid and within the Basque-Cantabrian Basin.



Depth map for an intra-Jurassic horizon showing the Ayoluengo-1 exploration well proposed location.

Under this new operatorship, the exploration effort was focused on the Ubierna permit, where photogrammetric studies, stratigraphic measurements, detailed surface geological mapping and modern reflection seismic data was acquired during the early 1960s. These studies resulted in the identification of a faulted anticline in the subsurface, below an Upper Cretaceous carbonate flat plateau – an agricultural terrain mostly dedicated to growing potatoes and locally known as "Loras." Although this faulted anticline was suspected from surface mapping, it was the first properly matured seismic prospect to be tested north of the Burgos area.



NAVARRO

Jorge Navarro, president of the AAPG-affiliated Association of Spanish Petroleum Geologists and Geophysicists (AGGEP), is geology manager at CEPSA E&P where he is responsible for coordination, management and supervision of the petroleum geology studies and works in regions where CEPSA E&P is currently active: South America, North/East Africa, Middle East, South East Asia and Spain. He also is a member of the CEPSA E&P geosciences quality assurance committee, which validates geological works, hydrocarbon prospects, volumetrics and risks, geological modeling, exploration and development well proposals. He holds a bachelor's degree in geology from the Complutense University in Madrid, Spain. Before joining CEPSA E&P in 1997, Navarro worked for REPSOL as exploration and development geologist in Syria and offshore Spain. He has been a lecturer on petroleum geology at several Spanish universities, also leading geological field trips and he is an active member of EAGE and PESGB.

The Well at Ayoluengo

The location of the first exploration well was carefully chosen jointly by Amospain and CAMPSA's engineers and geologists. It was named Ayoluengo-1, as per the small village nearby, and located some 15 kilometers southwest of the Zamanzas Valley, where previous shallow exploration drilling by CAMPSA had been concentrated. The well was designed as a 3,500-meter deep test of the Cretaceous sandstones, the Lower Jurassic marine carbonates, which had commonly recorded oil shows in the old CAMPSA wells, and the Triassic section.

The well was spudded on May 5, 1964. From 990 to 1,346 meters' depth, numerous poor shows of oil were observed, none worthy of further interest. On June 2, at 1,346 meters, the well penetrated a 5-meter thick sandstone bed of Late Jurassic-Early Cretaceous age with significant oil and gas shows.

The geological personnel assigned permanently to the well at that moment were William "Bill" Thornton Stoeckinger, an American geologist working for Standard Oil Company of California, and Cristobal Racero, a Spanish mining engineer working for CAMPSA. A first drill stem test was run, but the testing tool failed. In order to improve the hole conditions for testing, the well was deepened a few meters and a conventional core was cut over a very hard shaly section, just below the oil-bearing sandstones. Then, a second DST (at 1348-1361 meters) was run on Saturday, June 6, a warm and sunny day.

The tool was opened at 8:55 a.m. with an immediate good blow that rapidly increased to strong. The oil rushed up the hole and flowed up to a height of some 30 meters above the ground, spraying oil across the drilling site, vehicles and a nearby cropland. The flow period was one hour and was estimated at 85 barrels of 36-degree API oil per day.

The well was rapidly controlled and euphoria spread at the rig site, especially among the Spanish technicians from CAMPSA who for the first time had witnessed such an oil flow in their country. The church bells in nearby villages began to ring, and inhabitants came to the well location to witness the oil flow and to celebrate the discovery by toasting with champagne, shooting fireworks and collecting some oil samples as souvenirs.

Meanwhile, CAMPSA employees were carefully planning how to smoothly communicate this exciting news to Ruperto Sanz, the CAMPSA exploration manager. He was a Spanish mining engineer who had been one of the petroleum exploration pioneers in Spain, as well as a strong supporter of foreign investment who was fully persuaded of the commercial oil possibilities in this region.

Spain's "Oklahoma"

Ayoluengo was the first commercial oil discovered in Spain after more than 100

Continued on next page

Continued from previous page

dry holes. It brought great expectation to the region, presumed to become a prolific "black gold" producer. The oil discovery gained national attention with wide coverage by the media, which attracted many visitors to the well site, as shown in the photograph taken in June 1964.

Rumors and speculations abounded in the national press as debate and discussion about the importance of the discovery, the size of the reserves and the quality of the oil made headlines. An "Oklahoma Oil Boom in Spain" was a ubiquitous headline in some national newspapers.

To avoid speculation, trading of CAMPSA shares on the Madrid Stock Exchange was suspended for several days. The radio, television and the popular "No-Do" (from "Noticiarios y Documentales," or "News and Documentaries"), a state-controlled series of cinema newsreels that contained servile reporting in favor of the Franco regime, widely broadcasted the good news. News of the discovery of the first oil in Spain being so widespread, well site geologist Bill Stoeckinger became a sort of celebrity in Madrid.

According to Ina Stoeckinger, Bill's wife, "Bill was often recognized and congratulated on the street by total strangers who had seen him on the television news covering the story."

CAMPSA's Ruperto Sanz was also continuously requested by the media to release data related to the Ayoluengo discovery, even directly contacted by some government members to provide them with "original, unfiltered information."

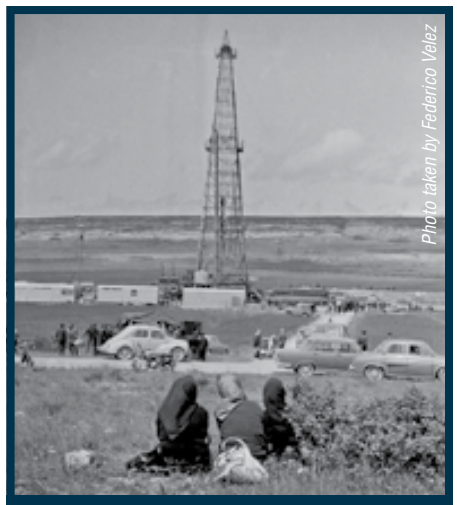
The two Spanish mining engineers, Sanz and Cristobal Racero, were decorated in May 1965 by the Spanish Government for their "outstanding participation in the Ayoluengo discovery."

After the well testing, Ayoluengo-1 drilling continued to the top of the Triassic, reaching a total depth of 2,397 meters on July 18, 1964. An oil zone in the Lower Jurassic was tested, flowing a small amount of 41-degree API oil, which was considered as non-commercial. The well was plugged back and completed in the upper sandstone bed.

The Ayoluengo-1 discovery well appeared to have been drilled on the northwestern flank of the anticline and not on the crest. Further appraisal and delineation drilling at higher structural positions resulted in the discovery of additional and thicker oil-bearing sandstones, but also evidenced a high degree of vertical and horizontal compartmentalization, showing that the structure was a complex anticline divided by several normal faults.

The Ayoluengo field, as we know today, consists of a northeast/southwest-oriented salt-cored anticline, related to Triassic salt movements. The field covers an area of 10 square kilometers and the structure has a vertical closure of about 200 meters. The structure is divided into two structural blocks by the Ayoluengo normal fault with 250 meters of vertical throw that affects the Jurassic carbonates up to the surface. The field produces from a series of thin lenticular fluvio-lacustrine sandstones packages of Late Jurassic-Early Cretaceous age.

More than 50 separate oil and gas sandstone beds have been identified. Some beds are as thick as 10 meters, but the average is only two or three meters. Areal extent of these lenticular sandstone bodies varies widely. Some are quite restricted, while others are laterally continuous. The sandstones have mean porosity values of 18 percent and permeabilities up to 1 Darcy. Because of the number of fault blocks and the rapid lateral changes in sand percentage, the thicknesses of the oil columns are also extremely variable.



Ayoluengo-1 drilling rig in June 1964, a few days after first oil was tested.

(Right) Ruperto Sanz, exploration manager in CAMPSA and one of the pioneers of petroleum exploration in Spain.

Most of the individual reservoir layers are isolated by shales and compartmentalized by faults, making the Ayoluengo not a single field but a grouping of more than 100 independent small accumulations. The reservoir drive mechanism is primarily gas expansion and gravity drainage. Oils present different physical properties from well to well and from sand to sand, with gravities ranging from 20 to 39 degrees API, which evidences the complexity of the petroleum system. The organic-rich marls and black shales of Liassic age have been largely considered the only source of the oil, but this is still far from clear.

In 1965, two distinguished persons visited the Ayoluengo field: Juan Carlos and Sophia, then the prince and princess, later king and queen of Spain. The visit caused some nervousness and embarrassment to the American technicians and executives because they did not know the protocol for how to greet and interact with royalty. It is reported by some witnesses that, during the visit, when opening a choke in a well head, some oil sprinkled the Princess' white mink coat, but that she just shrugged it off.

An exploitation concession named "Lora," partially derived from the Ubierna exploration permit, was awarded in December 1966. Some discussions were held for laying a 150-kilometer oil pipeline to the port city of Bilbao or even building a refinery in Burgos, as was requested by the local authorities.

Finally, at the end of 1966, a 11-kilometer pipeline was completed from the field's central facilities to a cargo terminal on the Burgos-Santander highway, 300 meters lower in altitude. The first Ayoluengo oil production started in 1967, reaching the peak production at 5,200 barrels of oil per day in 1969. Since then, production has gradually decreased. The pipeline was dismantled in 1993 and all the production is now transported by tanker trucks.


STOECKINGER

The Ayoluengo oil is paraffinic with relative high arsenic and vanadium content, which damages catalysts and makes it inadequate for refining. An alternative market was found and production was sold as fuel oil to local users in northern Spain, which continues today. Oil is produced by rod pumps, locally and popularly known in Spanish as "caballitos." The small amount of produced natural gas is used to power the rod pump motors and to generate the electricity used in the field. Produced water (around 50,000 parts-per-million sodium chloride) is reinjected in one disposal well.

A total number of 52 wells have been drilled in the field, the last in 1990. At present time only 10 wells are active. Many of the infill wells encountered undepleted oil-bearing sandstone beds, indicating the field complexity. A 3-D seismic of 390 square kilometers was acquired in 1988, aimed at identifying undrained reservoir beds and better estimating remaining reserves. Unfortunately, poor results were obtained.

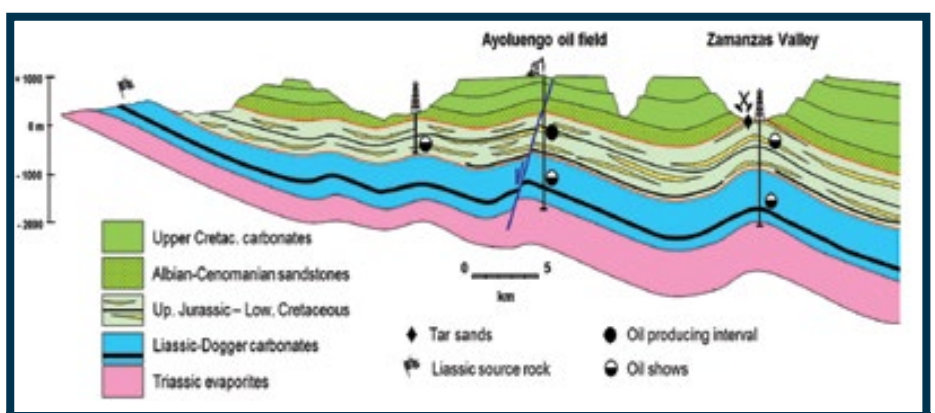
Fifty years later the Ayoluengo field is still active. After several changes in operators and partnerships, the current field operator is Compañía Petrolífera de Sedano S.L. (CPS), a subsidiary of the British company Leni Gas & Oil plc. The current average production is some 150 barrels of oil per day and the accumulated oil production nearly 17 million barrels of oil.

The Oil Museum in Sargentes de la Lora

Deep river erosion in nearby areas allows observation in spectacular geological exposures of most of the elements of the Ayoluengo petroleum system: tar impregnated sandstones, the claimed Liassic source rock and textbook faulted anticlines. Furthermore, the possibility of seeing working rod pumps in the field and of visiting the surface production facilities, together with the large amount of well data and seismic coverage available, has long made the Ayoluengo field an ideal training ground, providing students and non-technical people an excellent demonstration of a working petroleum system.

The region provides an excellent opportunity to initiate people into the oil exploration and production industry, now enhanced by the March 2015 opening of the Oil Museum in Sargentes de la Lora (Burgos). The museum is the first of this category in Spain, and is sponsored by the municipality of the village of Sargentes de la Lora and the Fundación Repsol in collaboration with – among others – the University of Burgos and the AAPG-affiliated Association of Spanish Petroleum Geologists and Geophysicists (AGGEP).

The museum is focused on the upstream, introducing the petroleum system concept and the wide variety of geological, geophysical and engineering techniques used in exploration and production. An important part of the exhibition is dedicated to the Ayoluengo field geology and its history, captured in an excellent collection of photos provided by the villagers and local newspapers, together with press clippings, documentaries of the mid-60s, educative panels, geological 3-D models, drilling and production material and an authentic working rod pump. The museum is located inside Las Loras Geopark project.



Schematic regional cross section through the Ayoluengo oil field. The deep erosion by rivers in nearby areas allows observe on outcrops most of the elements of the Ayoluengo petroleum system. It allows observing tar impregnated sands in the core of a spectacular surface anticline. Also are observed outcrops of the black shales of Liassic age which have been largely considered as the only source rock for the Ayoluengo oil.

A Gordian Puzzle?

The Ayoluengo discovery revitalized seismic and drilling activity in the region, but subsequent exploration wells during the 1970s and '80s only tested non-commercial oil flow rates.

After years of intense exploration activity, surprisingly, the Ayoluengo field still remains a unique oil discovery as the only onshore commercial oil field in Spain and also the only one in the entire Iberian Peninsula. This geological singularity has brought recurrent discussions among petroleum geologists because it is difficult to explain why a petroleum system is uniquely working at this particular spot and nowhere else within such a vast territory.

Despite a long history of hydrocarbon exploration, the Basque-Cantabrian Basin is still considered one of the most prospective sedimentary basins in Spain and, at the present time, most of the exploration activity for conventional and non-conventional plays is mainly concentrated in this region.

OCS Issues Drive Policy Debates

By EDITH ALLISON, Geoscience and Energy Policy Office Director

Three outer continental shelf (OCS) oil and gas issues were prominent in 2015 policy debates: Atlantic offshore, including permitting seismic surveys and a new five-year lease sale plan; new rules for offshore drilling equipment, notably blowout preventers; and new rules governing Arctic drilling. The topics will continue in the policy limelight in 2016 as the federal government moves to release final versions of the permits, plans and rules.

Presidential and/or congressional moratoria on oil and gas exploration in the Atlantic OCS started in the mid-1980s.


ALLISON

An important driver for new rules is the fact that loss of well control incidents are occurring at the same rate as before the Macondo blowout.

The moratoria were lifted in 2008 and Atlantic OCS lease sales were planned. However, after the Deepwater Horizon blowout, drilling was again banned in the Atlantic OCS.

The current (2012-17) OCS leasing plan initially allowed leasing only in the historically active areas of the western and central Gulf of Mexico and Alaska's Beaufort and Chukchi seas and Cook Inlet. This fall, the Obama administration further restricted oil and gas leasing by canceling 2016 and 2017 lease sales in the Beaufort and Chukchi seas.

The mid- and south-Atlantic planning areas may be included in the 2017-22 OCS leasing plan the Bureau of Ocean Energy Management (BOEM) began developing in 2014.

The draft for the proposed 2017-22 leasing plan released for comment in January 2015, includes Atlantic, Beaufort Sea and Chukchi Sea lease sales. The next version will reflect public comments received in 2015, and will be available for additional public comments in the first half of 2016. Whether it will include Atlantic and Arctic areas is unknown.

Separately BOEM decided in July 2014 to allow seismic (geological and geophysical, or "G&G") surveys in the Atlantic OCS. Several companies applied and a lengthy public comment and review process continues. The most recent activities include:

- The National Oceanographic and Atmospheric Administration (NOAA) recently completed review of four applications from seismic companies under the Marine Mammal Protection Act. BOEM still has additional work to complete its review, which could take many months.
- In early December, Representatives Mark Sanford (R-S.C.), Bobby Scott (D-Va.) and 29 others sent a letter to BOEM asking for a halt to the use of seismic airguns in the Atlantic. The legislators claim that close to 90 towns, cities and counties along the Atlantic coast have passed resolutions opposing seismic testing and/or drilling. Representing different opinions, the Outer Continental Shelf Governors Coalition, which includes governors of North Carolina, South Carolina, Virginia and Maine as well as Gulf Coast states and Alaska, has called for keeping mid- and south-Atlantic leasing in the 2017-22 plan.

Proposed Well Control Rule

The Bureau of Safety and Environmental Enforcement (BSEE) released its proposed well control rule in April and is now considering thousands of pages of technical comments from more than 170 commenters.

In December, the Senate Energy and Natural Resources Committee (ENR) conducted a hearing on the well control rule and offshore oil and gas regulations, where Brian Salerno, BSEE director, testified about the well-control rule. Salerno declined to predict what revisions BSEE will make in the final rule or when it will be released.

The hearing illuminated the differing opinions on some of the most contentious elements of the proposed rule:

Salerno testified that the new specifications for design, repair and maintenance of blowout preventers (BOP) incorporate the recommendations of multiple investigations and studies of the Macondo blowout, and numerous meetings with industry.

He noted also that an important driver for new rules is the fact that loss of well control incidents are occurring at the same rate as before the Macondo blowout.

Continued on next page

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He identified major areas of contention to the draft rule: drilling margins, blowout preventer inspections, accumulator capacity and real-time monitoring. He also acknowledged industry concerns about overly proscriptive language and potential unintended consequences of the rule.

Erik Milito, group director for upstream and industry operations at the American Petroleum Institute (API) complained that industry experts did not get sufficient time or enough meetings with BSEE staff to fully comment on the well control rule, but he thanked BSEE for scheduling an additional meeting later in December.

He objected to the rules' lack of flexibility to allow for the unique conditions of each well. He also voiced concerns about proposed modifications to BOPs and expanded BOP testing schedules that could create additional risk for safe operation of the equipment. In addition, Milito quoted economic analyses that showed the 10-year cost of the rule to industry would be $32 billion – an eye-catching 36-times greater than BSEE's cost estimate of $883 million.

Jaqueline Savitz, vice president for U.S. oceans at Oceana, stated that her group considers the rule to be a significant improvement over existing regulations, although not sufficiently robust. She recommended the use of dual blind shear rams in BOPs to provide needed redundancy. Savitz also stated concerns that the compliance times – as much as seven years – were too long, creating unnecessary risk until industry installs improved equipment. She also recommended larger penalties for industry noncompliance and increased government oversight.

Arctic OCS

BSEE is working to finalize its Arctic drilling rule even though there is no expectation of any Arctic activity for many years, due to Shell canceling its Chukchi Sea drilling plans and Statoil's announcement that it would exit all of its existing Chukchi Sea leases.

The most contentious elements of the draft rules are those calling for a stand-by rig capable of drilling a relief well, a shortened drilling season, and the requirement for the capability to capture oil using only mechanical techniques (i.e., excluding burning or using dispersants).

At the December hearing, Milito described substantial economic and employment impacts from federal policies that keep the huge potential Alaska oil and gas resource from being developed. He also recommended performance-based rules that would allow equivalent technologies, rather than the proposed rigid requirements. He also observed that some of the BSEE proposals could decrease safety and increase pollution, for example, by requiring more vessels at a drilling location.

Sen. Maria Cantwell (D-Wash.), ranking member of the ENR committee, stated that six to eight loss of well control incidents each year "emphasize the need for comprehensive and robust safety standards."

Cantwell also pointed out that, according to the U.S. Coast Guard, there is no way to clean up oil in ice. For that reason she recommended that the Arctic and well control rules be finalized quickly.

Mark Rockel, principal consultant at Ramboll Environ, testified that because of the low probability of a blowout of the shallow, low-pressure exploration and appraisal wells expected in the Arctic offshore, the cost, over 20 years, of the same season relief well requirement would overwhelm potential benefits. He also stated that use of performance-based seasonal drilling limits and use of alternative spill mitigation would reduce costs and be more effective.

In case readers are wondering about the rules under which Shell drilled its Chukchi Sea well this summer – those were included in its revised exploration plan negotiated with BOEM in 2015. The plan generally mirrored the preliminary Arctic drilling rule.

The preliminary 2017-22 leasing plan includes lease sales in both the Beaufort and Chukchi seas, although a 25-mile near-shore exclusion zone would be added to the Chukchi Sea area.

Good news from the Gulf of Mexico

In the meantime and in the midst of declining oil prices, new projects in the Gulf of Mexico have come online, and offshore U.S. production rose to over 1.68 million barrels per day in September, offsetting declines in some shale-producing regions, according to the Energy Information Administration.

Register for AAPG Congressional Visits Days

Join your colleagues and the AAPG Geoscience and Energy Policy team in Washington, D.C. for Congressional Visits Days, March 14-16, 2016.

Through CVD, you can advocate for issues important to our members, including rulemakings impacting hydraulic fracturing and methane emissions, increased access to onshore and offshore federal lands, and federal research to improve technology and build a STEM-proficient workforce.

Your participation helps raise visibility and support for petroleum geoscience in Washington, helping to make AAPG a top resource for policymakers seeking technical information on oil and gas issues.

The registration deadline is Feb. 16.

To register, reserve a hotel room at the Army and Navy Club, or get additional information on CVD or Washington, D.C., contact Edith Allison at eallison@aapg.org or 202-643-6533, or visit www.aapg.org/about/aapg/offices/policy.

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

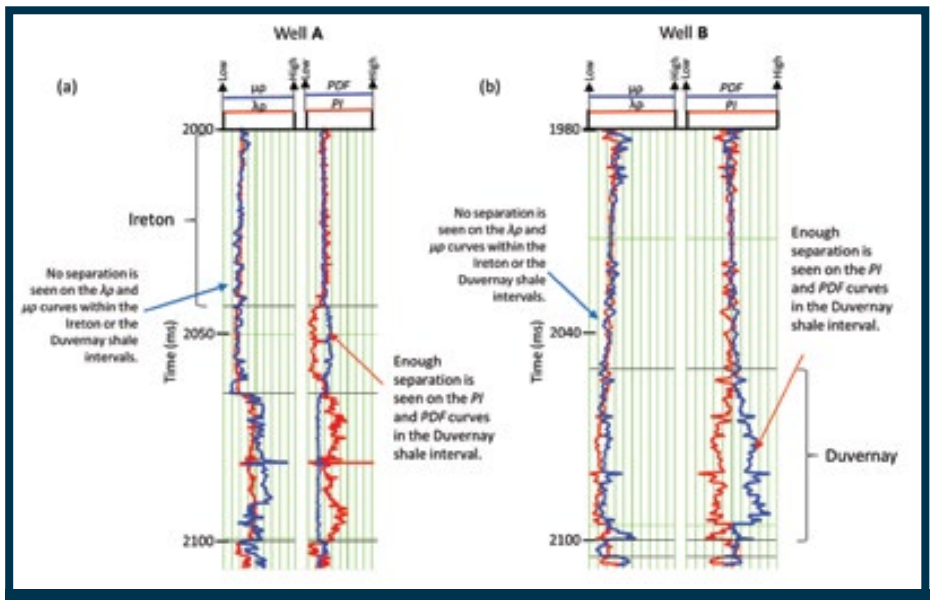

Figure 1: Comparison of λρ – μρ and PI-PDF well log curves. On scaling the curves such that they are seen to overlay for the background lithology, no separation is seen on the λρ – μρ curves in the Ireton and Duvernay shale sections while enough separation is seen on the PI and PDF curves for well (a) A and (b) B.

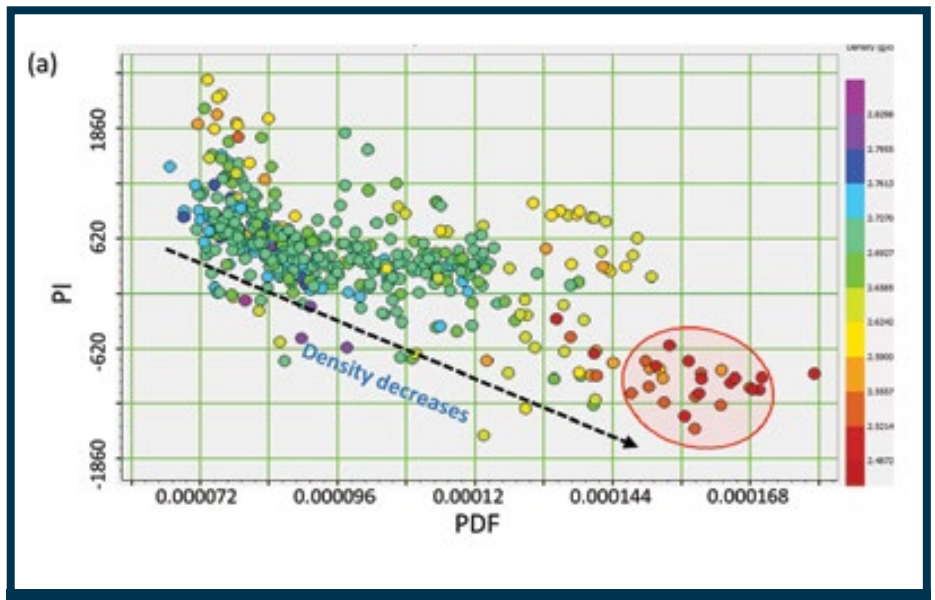

Figure 2(a): Crossplot of PI vs PDF attributes computed for well log data for the time interval shown in figure 1, color-coded with density. It is noticed that density decreases in the direction of the black arrow. Points corresponding to low density (high PDF, low PI) are enclosed in the red polygon as they show the characteristics of a source rock.

Poisson Impedance Application to Shale Resource Characterization

By RITESH KUMAR SHARMA and SATINDER CHOPRA

The main goal for shale resource characterization is usually the identification of sweet spots, which represent the most favorable drilling targets.

Such sweet spots can be identified as those pockets in the target formation that exhibit high total organic carbon (TOC) content, as well as high brittleness. This is based on the fact that the higher the TOC in a formation, the better its potential for hydrocarbon generation, and the higher the brittleness, the better its fracability.

SHARMA

CHOPRA

The TOC content is usually determined from well log data and calibrated with the available core data. But such a determination can only be made at the location of the wells, even though we wish to determine this property in a lateral sense.

We thus turn our attention to seismic data. As there is no direct way of computing TOC using seismic data, we adopt indirect ways for doing so.

Separating Gas Sand Reservoir From Background Lithology

TOC changes in shale formations are expected to influence the P-velocity (V_P), S-velocity (V_S) and density (ρ) of those formations. Consequently, it should be possible to detect changes in TOC from surface seismic response through the impedance inversion process.

During the last decade, prestack impedance inversion has been used to compute the P-impedance (I_P), S-impedance (I_S), V_P/V_S and density attributes, amongst others. Of course, the robust determination of density from seismic data requires very long-offsets and noise-free data, which are seldom available. So as to avoid this stringent requirement for determination of density, usually product-attributes are computed. Examples of such attributes are λρ, μρ, κρ and Eρ, where λ and μ are the Lame's constants, ρ is the density, κ is the bulk modulus or the incompressibility, and *E* the Young's modulus of the rock.

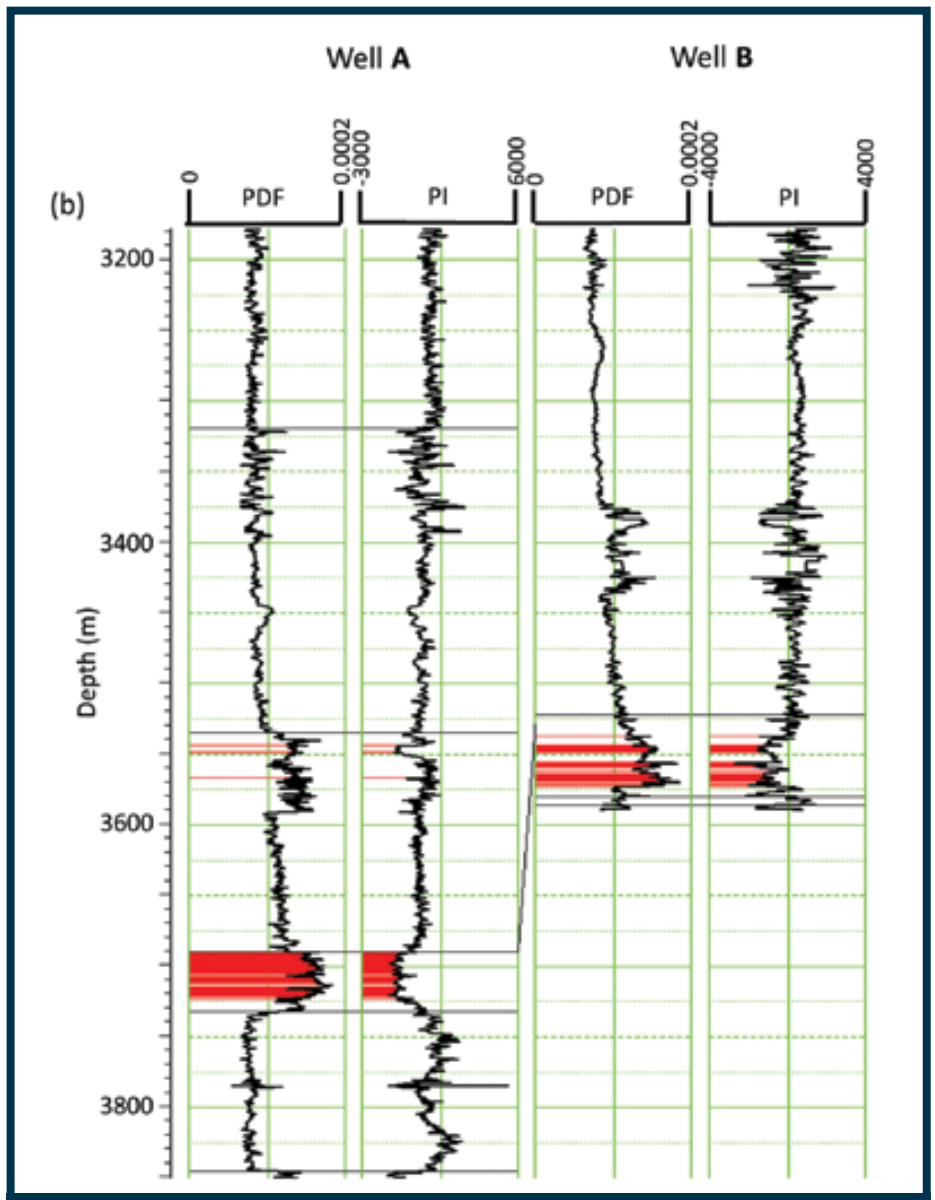

Figure 2(b): Back projection of enclosed points on the well log curves shows that these points are coming from the Duvernay zone for both the wells.

In the case of conventional reservoirs, it is usually noticed that on a crossplot of I_P vs I_S, the cluster of points coming from a gas sand reservoir tend to separate out from the cluster that represents the background lithology. The extent of separation between such clusters depends on the impedance contrast between the litho-fluid and the background lithology.

Enhanced separation between clusters of points representing gas sands and those that represent the background lithology is sought by crossplotting other combinations of seismic attributes such as λρ and μρ. Gas sands usually exhibit lower values of λρ and high values of μρ, and are generally seen to exhibit a somewhat better cluster separation, though it may not be always the case. In the latter case, an interesting attribute called "Poisson impedance" (PI) has been suggested to work better. Mathematically, *PI* is given as $PI = I_P - cI_S$, where the index c describes the optimum rotation of the cluster of points in the I_P vs I_S crossplot space for obtaining better litho-fluid discrimination. The value of '*c*' is determined as the inverse of the slope of the regression line on an I_P vs I_S crossplot. *PI* shows better discrimination of pay sands from the background lithology.

With this done, we may still be faced with the issue of variation in sand quality, i.e. the ability to separate clean sands from shaley or dirty sands. For this purpose, another attributes known as *Poisson dampening factor* (*PDF*) was introduced and is mathematically given as:

$$\frac{D}{\rho} = \frac{I_P + \sqrt{2}I_S}{2\,(I_P^2 - I_S^2)}$$

A crossplot of *PI* vs *PDF* is found to be interesting as it helps with lithology discrimination and extended characterization of sand quality. Good quality or clean sands exhibit high values of *PDF* and low values of *PI*.

Application to the Duvernay Formation

Armed with all this information about *PI* and *PDF*, we decided to apply it to an unconventional reservoir, i.e. the Duvernay Formation of central Alberta, Canada. The Duvernay shale play has been recognized as the source rock for many of the large Devonian oil and gas pools in Alberta, including the early discoveries of conventional hydrocarbons near Leduc, south of Edmonton, Canada. We began with the well log data and crossplotted different attributes, which can be derived seismically. The commonly considered pairs of attributes for the purpose are I_P - I_S, λρ – μρ, I_P – V_P/V_S, etc. As discussed above, for conventional gas sand reservoirs, λρ and μρ pair of attributes is found to be superior to the I_P - I_S pair, or some other attributes in terms of fluid and lithology

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discrimination. We make a comparison of λρ - μρ with *PI* - *PDF* attributes. Figure 1 shows this comparison. The panels to the left in figures 1a and b show the λρ (red) and μρ (blue) curves for wells A and B. The curves are scaled in such a way that they overlay each other for the background lithology (in the present case the zone marked above the Duvernay formation).

In the Duvernay zone (source rock), we expect lower λρ values and somewhat higher values of μρ, compared with a non-source rock. However, we do not notice this on the λρ and μρ curves in figures 1a and b. On the right panels in figure 1a and b, we have plotted *PI* and *PDF* curves, again scaled so that they overlap in the background litho-intervals as for the λρ and μρ curves. Notice that the *PI* and *PDF* curves show a crossover separation in the Duvernay intervals in the two wells with respect to the background litho-intervals. With this encouraging observation, we crossplotted *PI* and *PDF* for both the wells for the same intervals, color-coded with density values and is shown in figure 2. Data points corresponding to very low density correspond to high *PDF* values and low *PI* values, which may be considered favourable for source rocks. To ascertain the location of these points on the log curves, we enclose some points on the crossplot in a polygon and back-project them on the log curves. Notice in figure 2b, the data points come from the Duvernay zone in both the wells.

We now turned our attention to deriving the *PI* and *PDF* attributes from seismic data. As these attributes are a function of I_P and I_S, we need to compute both these attributes using simultaneous or joint impedance inversion. Both these types of impedance inversion technique have been discussed by the authors in an earlier GeoCorner article (July 2015).

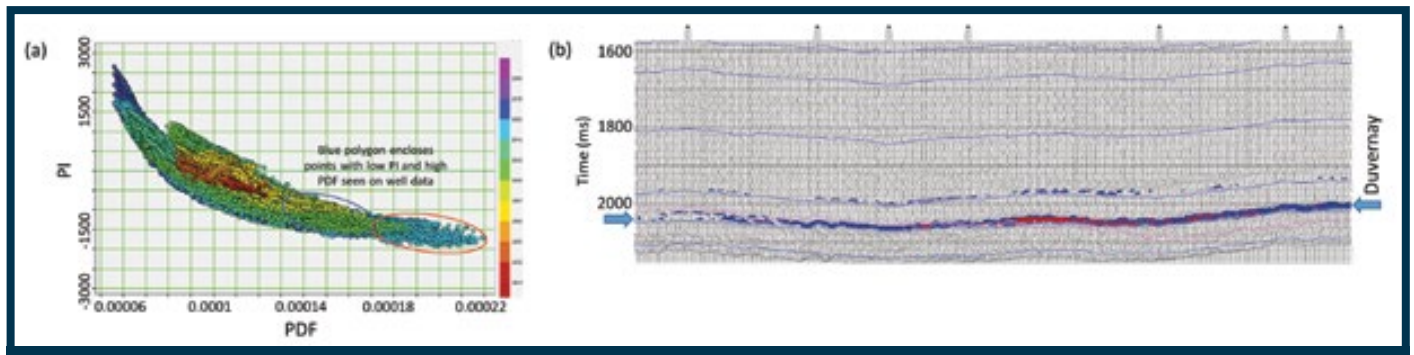

Figure 3: (a) Crossplot of PI and PDF attributes derived from post-stack joint inversion along an arbitrary line that passes through the different wells over a zone that covers the Duvernay formation. Blue polygon encloses points with low PI and high PDF seen on well-log data for the Duvernay formation. Points enclosed by red polygon show lower values of PI and higher values of PDF than the values of points enclosed by blue polygon. (b) Back projection of these two polygons shows the prospective zone in the Duvernay shale.

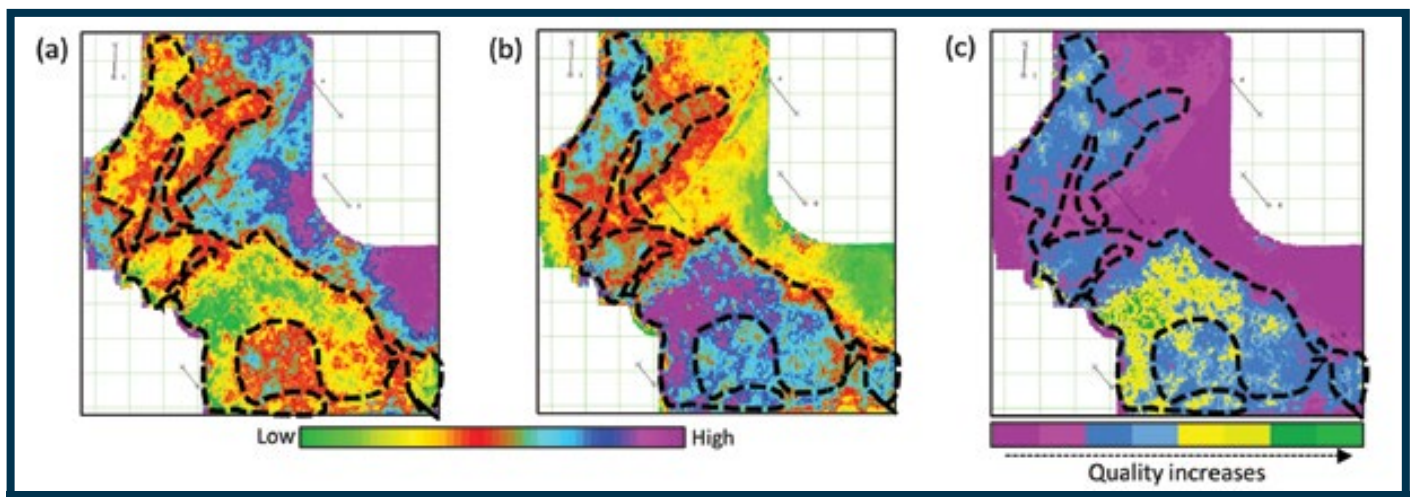

Figure 4: Horizon slices from (a) PI and (b) PDF attribute volumes averaged over a 10 ms-window above the Duvernay base horizon. As low PI and high PDF correspond to the Duvernay formation, the presence of Duvernay formation has been mapped laterally as indicated with the black outline. However, within the Duvernay formation the quality of it is shown in (c).

We picked up post-stack joint inversion data for the present study, which uses the *PP*- and *PS*-stacked data from a multicomponent seismic survey over the area.

Employing the *P*-impedance and *S*-impedance low-frequency impedance models, and the appropriate wavelets

See **GeoCorner**, page 41

Gifts of Time Build a Solid Foundation

By APRIL STUART, AAPG Foundation Programs Coordinator

Time is a precious commodity to us all, and is particularly treasured by geologists who have a unique relationship with the concept of time. A geologist's mind is trained to leap backward and forward by epochs, which stands in stark contrast to most people's frames of reference, which are typically measured by minutes or days, or decades at most.

Time is an especially precious commodity when it is given to the AAPG Foundation, in whatever increment.

Since its inception, the success of the AAPG Foundation has been fostered by generous volunteers, all of whom share a deep passion for advancing the geosciences.

Those same volunteers who have contributed with their treasure have also dedicated their time and talents to creating programs that will encourage and financially assist like-minded scientists aspiring to do the same.

Foundation volunteers serve in many capacities. They donate time and talent serving as Trustees, Members of the Corporation and Trustee Associates. Many AAPG Foundation supporters also donate a considerable amount of time to the Foundation's program committees, all of which provide the guidance needed to shape the Foundation's impact.

These gifts of time and talent pay in big ways, and the Foundation would not be able to administer its key programs without them. Their leadership supports many of the administrative efforts of the programs, such as scoring and selecting scholarships to students, grants for select geoscience initiatives, education awards honoring geoscience teachers and professors, and more. You too can get involved in one or more selection committees.

Foundation volunteers pause at 2015 ACE. (L-R) MVSP Committee chair, Don O'Nesky, MVSP Committee member Meg Kremer and AAPG Foundation chair, Jim Gibbs.

A Multitude of Committee Efforts

The longest standing committee is the 60-person strong Grants-in-Aid Committee, a joint AAPG/AAPG Foundation Committee, chaired this year by longtime volunteer Mike Unger. The Grants-in-Aid Committee and its leadership spends a significant amount of time reviewing and scoring masters and doctoral research projects and will award $260,000 in research funds 2016.

The Military Veterans Scholarship Program Committee, chaired by Don O'Nesky, will soon begin its second year of reviewing applications submitted by veterans who are studying geoscience at the undergraduate level.

The newly established L. Austin Weeks Committee, chaired by AAPG Emeritus member Ron Nelson, will soon begin applications for grants submitted by undergraduate geoscience students and their respective student organizations, awarding top students and organizations with $500 grants.

The Professorial Award panel, led by Carol Wicks, chooses one university or college professor who has shown excellence in his or her field.

Our Teacher of the Year Award panel, led by Laura Zahm, annually selects one K-12 teacher who has demonstrated earth science excellence to youth among his or her peers, who receives a cash award and an expense-paid trip for two to ACE.

The Foundation welcomes new volunteer interest to participate on the committees described. If you are interested in donating time and would like to learn more about volunteering for one of the Foundation's program committees, please email program coordinator, April Stuart, and express your interest at astuart@aapg.org or call (918) 510-2644.

PROFESSIONAL newsBRIEFS

David Allard, to general manager-southern region, QEP Energy, Denver. Previously geoscience manager-southern manager, QEP Energy, Tulsa.

Dan A. Billman, to president-elect, Pennsylvania Council of Professional Geologists. He will begin his term as president in 2017. Billman is president of Billman Geologic Consultants, Houston, Pa.

Robert J. Brewer, to president, Cepstrum Geophysical, Houston. Previously region business development manager, Baker Hughes, Houston.

Carl Fiduk, to senior geophysicist, Freeport McMoran Oil and Gas, Houston. Previously consultant/owner, Fiduk Consulting, Houston.

Andrew Miall has been awarded the Francis J. Pettijohn Medal in Sedimentology and the Geological Association of Canada's lifetime achievement award, the Logan Medal in 2014.

He received the Digby McLaren Medal in Stratigraphy from the International Commission on Stratigraphy in 2015. Miall is professor of geology at the Department of Earth Sciences and Gordon Stollery Chair in Basin Analysis and Petroleum Geology at the University of Toronto, Canada.

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POSITIONS WANTED

The College of Petroleum Engineering & Geosciences at King Fahd University of Petroleum & Minerals (KFUPM) in Dhahran, Saudi Arabia is seeking candidates for ten (10) new faculty members at the Assistant to Full Professor level, as well as research staff at the College's new Center for Integrative Petroleum Research (CIPR). Candidates applying for these positions are expected to hold a doctoral degree in Geology, Geophysics, Petroleum Engineering or related fields. These are full-time positions with teaching and/or research duties.

Located in Dhahran Saudi Arabia, the College of Petroleum Engineering and Geosciences at KFUPM is an integral part of KFUPM but with features that distinguish it markedly from other KFUPM Colleges:

- The Center for Integrative Petroleum Research (CIPR): This Center will be the home for the College's academic research enterprise, supporting curiosity-driven research, as well as performing problem-oriented contract research for both government and industry.
- High level of industry engagement: The new College will leverage, and expand on, KFUPM's long history of close engagement with industry in Dhahran Techno Valley, in the Kingdom, and worldwide. The new College, and particularly, the CIPR includes programs to draw industry interns, visiting industry executives, and visiting industry researchers and practitioners to the College to contribute to, and learn from, the College and its research activities.
- Integrated, collaborative curriculum: A critical role of the new college is to form talented undergraduate and graduate students into petroleum professionals characterized by the highest standards of technical expertise, innovation and teamwork. Over the course of the early years of the College, the classroom, laboratory, and experiential aspects of the core curricula will be revised to provide world-class interdisciplinary and integrative degree programs for students matriculating through the college.

The successful candidate will develop a strong funded research program, supervise graduate research, publish in peer-reviewed journals, and teach and develop graduate and undergraduate courses in the Geoscience and Petroleum Engineering curriculum. Evidence of strong qualifications will include a record of quality publications including the PhD dissertation a well thought out research plan and a statement of teaching philosophy.

Candidates must submit the following documents with the application:

1. Vision statement on research and teaching experience and philosophy;
2. Resume/Curriculum Vitae.

For more details and to submit an application, please contact:
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from the two seismic datasets in the broad zone of interest, the *P*- and *S*-impedance attributes are derived.

Figure 3a shows the crossplot of inverted *PI* and *PDF* along an arbitrary line passing through different wells over a zone that broadly covers the Duvernay interval. The overall shape of the cluster of points seen on this crossplot is similar to the equivalent crossplot obtained with well log data shown in figure 2a.

The cluster of points enclosed in the blue polygon are those that exhibit low *PI* and high *PDF* values on the log data for the Duvernay formation. The points enclosed in the red polygon show lower values of *PI* and higher values of *PDF* than the points enclosed in the blue polygon.

Analogous to the conclusions that we draw from such crossplots for conventional plays, we notice that as we go from the blue to the red polygon, the quality of shale should improve. The back projection of these two polygons on the seismic line shows the location of these points and as shown in figure 3b we observe these points highlighting the Duvernay interval. What we conclude here is that the red zone represents better quality shale that the blue zone. The presence of quartz (sand) in the clay decreases its density, which may lead to an increase in *PDF* values associated with it. Higher content of quartz enhances its brittleness, and thus the better quality of shale we refer to has a reference to its brittleness. The red zone thus may be considered being more brittle than the blue zone.

As we desire to identify sweet spots in a lateral sense over the interval of interest on a 3-D volume we generate horizon slices of *PI* and *PDF* over a 10 ms window above the base of the Duvernay interval, and are shown in figures 4a and b. We interpret low *PI* and high *PDF* values as corresponding to the Duvernay zone based on the above-mentioned observations, and are shown enclosed within a black outline.

Finally, based on the values of *PI* and *PDF* we compute the quality of the Duvernay shale, shown in figure 4c. The magenta color corresponds to the background trend, and the quality of the shale increases as we go from dark blue to light green colors.

In conclusion, thus we have demonstrated the characterization of the Duvernay shale in terms of *PI* and *PDF* attributes in a qualitative way, both on well log and seismic data. We suggest the application of the above workflow for characterization of other shale plays and also ascertain how well the predictions are met on drilling.

We thank Arcis Seismic Solutions, TGS, for allowing us to present this work.

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of geothermal generating systems for different types of geothermal resource. At a few locations (e.g., Larderllo, Italy; The Geysers, California), the resource is dry steam at a temperature greater than 300 degrees. The steam is fed directly to a turbine, which turns a generator to produce electricity. More commonly the resource is water at a temperature of greater than 360 degrees, which is flashed to water and steam at the surface. The steam is fed to a turbine, which turns a generator to produce electricity and the water is injected back into the reservoir to maintain reservoir fluid volume. For both dry-steam and flashed-steam power plants, more than one stage may be connected in series with the steam pressure decreasing at each stage.

For geothermal resources with temperatures lower than about 350 degrees, a binary system is used. In the binary system the geothermal fluid passes through a heat exchanger where a secondary fluid with a lower boiling temperature than water is vaporized. The geothermal fluid is then reinjected back into the reservoir. The vaporized secondary fluid drives a turbine that turns a generator to produce electricity. The secondary fluid is cooled before returning to the heat exchanger resulting in a back-pressure on the turbine. Two types of secondary fluid are used in operating binary power plants, organic refrigerants, (the organic rankine cycle, or ORC), and a mixture of two components, typically ammonia and water (the Kalina Cycle).

Economic geothermal power generation systems are currently sited on geothermal resources with sufficient permeability to produce adequate flow to maintain the energy transfer required for the electricity production. Experimental systems have been explored in a few countries in which permeability has been enhanced by hydraulic fracturing or similar techniques (enhanced geothermal systems, or EGS), but these systems are still in the investigation stage.

Some geothermal waters, especially with magmatic heat sources, have a high mineral content with solutes that can include economic concentrations of silica, zinc, lithium, manganese, gold, silver and some rare earth minerals. After the heat has been extracted from the geothermal fluid, one or more of these minerals may be extracted, increasing the economic return of the geothermal operation.

Direct use of geothermal resources and geothermal power production make valuable contributions to the mix of renewable but they are geographically limited to where high temperatures are near the surface or where the use justifies the cost of drilling.

Ground-source heat pumps may be used at almost any location where space heating and/or cooling, and even hot water and refrigeration are required.

Heat pumps are not an energy source and consume electricity. However, the energy savings that result from replacing most conventional heating and cooling systems with ground-source heat pumps would make a large reduction in the quantity of electricity needed to be generated. The most efficient and cleanest electricity is the electricity that does not need to be generated.

Paul Morgan is chair of the Geothermal Energy Committee of AAPG's Energy Minerals Division. He is also senior geologist of the Colorado Geological Survey of the Colorado School of Mines, Golden, Colo.

DIRECTOR'S CORNER

When Will Oil Prices Go Up?

By DAVID CURTISS

This month our coverage has focused on the Middle East, a region rich in hydrocarbons and culture. These hydrocarbon resources will be discussed in great detail at next month's GEO 2016 conference in Bahrain.

This biennial event, organized by AAPG with support from the Society of Exploration Geophysicists and the European Association of Geoscientists and Engineers is a prime opportunity for geoscientists in the region to gather, learn and discuss how best to find and develop these resources.

But the Middle East is also a region experiencing significant geopolitical tension with the continued and expanding conflict with ISIL and the re-entry of Iran onto the global stage with the lifting of economic sanctions that had been in place for decades.

The region is also experiencing economic upheaval with lower crude oil prices dramatically increasing budget deficits in many countries at the same time as they seek to diversify their economies.

Events and trends in this part of the world can have dramatic impact on our industry and profession. And we're seeing it right now in crude oil prices.

The slide in crude oil started late last year and has accelerated in the past month. As I write this column, the WTI price is hovering just over $28 a barrel.

Everywhere I go and in every conversation I have with AAPG members, sooner or later – and it's usually sooner – I'm asked what I'm hearing about the duration of this low price cycle.

We've all heard the old saying that prediction is difficult, especially of the future. But with the news cycle full of stories of layoffs in the energy sector, bankruptcies both occurring and looming, and a global supply glut, it's hard not to get swept up in the panic.


CURTISS

> **In every conversation I have with AAPG members ... I'm asked what I'm hearing about the duration of this low price cycle.**

The price of oil is controlled by many variables, but the four most important are:

- Supply.
- Demand.
- Risk.
- Currency effects.

Unlike me, analysts at the U.S. Energy Information Administration (EIA) are in the prediction business. And while they do not, as far as I know, have special or secret information, they do have a systemized approach to monitoring and using data to develop price forecasts.

Supply and Demand

When you look at supply it's clear that the world is producing more than it's consuming. EIA's January 2016 Short Term Energy Outlook reports that global oil inventories grew by 1.9 million barrels per day in 2015 and they expect that trend to continue in 2016 with inventories growing by an additional 0.7 million barrels per day.

OPEC supply in 2015 averaged 31.6 million barrels per day with production increasing 0.7 million barrels per day in 2015 and EIA forecasts an additional 0.5 million barrels per day increase in 2016. The effect of Iranian oil reaching global markets may change these numbers. EIA expects Iran to grow its production by 0.3 million barrels per day in 2016 and 0.5 million barrels per day in 2017.

Non-OPEC supply increased by 1.3 million barrels per day in 2015 but EIA forecasts a decline by 0.6 million in 2016.

This supply growth has been driven largely by U.S. unconventional resource developments, which experience rather rapid production declines and don't require the long investment cycles of large offshore installations, for example.

The world is producing more oil, and that is pushing crude oil prices lower.

But the world is also consuming more oil.

In 2015 the EIA estimates the globe consumed an average of 93.8 million barrels per day and they expect that demand to grow by 1.4 million barrels per day in both 2016 and 2017.

Think about that number: 93.8 million barrels per day is roughly 1,085 barrels per second. And, while demand growth may be slowing, it's still growing year after year as people are born and begin consuming energy, as economies grow and people seek higher standards of living.

Eventually, this additional demand will sop up the excess supply.

Risk and Currency

Risk is another variable that hovers over crude oil markets.

A disruption of supplies to crude oil markets can quickly cause prices to spike. Current prices indicate that the market doesn't seem to fear a disruption, notwithstanding the regional geopolitical tensions. But, events have a history of proving the market wrong.

Finally, a strong U.S. dollar is pushing down crude oil prices. Currencies do not have an absolute value, but rather are valued against something else.

Crude oil is valued against the U.S. dollar, and if you plot crude oil prices against the U.S. dollar index over the past five years, you see a strong inverse correlation between the two: As the dollar weakens the price of crude oil rises and as it strengthens the price of crude oil drops. That correlation is particularly pronounced today.

Many variables control crude oil prices, but these four are the most important variables.

Low prices cure low prices in commodity markets. I don't know when that is going to happen, but our job is to be ready when it does.

DIVISIONS REPORT: EMD

Geothermal's Contributions to the Energy Equation

By PAUL MORGAN

The Energy and Minerals Division of the AAPG focuses on unconventional hydrocarbon energy resources, such as coalbed methane and gas hydrates and alternative energy resources, such as coal, uranium and geothermal energy.

These resources are important to members of AAPG not only because they compete with conventional hydrocarbon resources but also because they often share technologies in exploration and production. High-temperature geothermal resources share many of the temperature challenges that are found in deep oil and gas wells.

This article takes a broader look at geothermal resources in terms of their overall contributions to the energy use equation.

Geothermal is a renewable resource with a useful temperature range from ambient to more than 650 degrees Fahrenheit. In addition, it can be a source of important minerals.

Uses of the geothermal resources fall into three categories. These are, in order of increasing temperature: ground-source heat pumps, direct use and geothermal electricity generation.

Ground-Source Heat Pumps

Ground-source heat pumps, also known as geothermal or geoexchange heat pumps, use the near surface of the earth as a thermal reservoir at ambient or near ambient temperatures. They do not use heat directly from the interior of the Earth, but use a heat pump to move heat from inside a building to the ground in the summer and from the ground to the building in the winter.


MORGAN

> **Approximately half of the energy consumed in an average home in the United States, and in many governmental, commercial and industrial buildings, is used for heating and cooling.**

A heat pump is the main cooling component in a refrigerator or refrigerated air conditioning. In a refrigerator, heat is transferred from the icebox to cooling coils outside the refrigerator. In refrigerated air conditioning, heat is moved from inside a building to cooling coils outside the building. However, a ground-source heat pump is reversible and can transfer heat out of the building in the summer and into the building in the winter.

Approximately half of the energy consumed in an average home in the United States, and in many governmental, commercial and industrial buildings, is used for heating and cooling. Ground-source heat pumps are very efficient for heating and cooling, operating with 20-50 percent of the energy consumption of conventional systems. Widespread adoption of ground-source heat pumps could reduce electricity demand in the United States by 10-30 percent, with a similar reduction in carbon emissions.

Many relatively small-scale domestic, commercial and industrial uses of fuel and electricity are for low-temperature applications or hot water. These uses include space heating, greenhouse heating, aquaculture, food processing and preparation, and timber drying. The most efficient source of heat and water for these processes may be direct-use geothermal hot water, as no energy conversion is required to provide the heat and water.

Sources of hot water at the surface – thermal springs – are geographically limited and are often further limited by existing users, most commonly spas. However, as is known by all drillers and most members of AAPG, temperatures of 212 Fahrenheit and higher are commonly encountered at typical drilling depths for oil and gas. Where energy prices are high, and multi-story apartment buildings are common, such as in Germany, deep geothermal may be economic to produce hot water for space heating.

These conditions are not common in the United States, but hot produced water is a common by-product of oil and gas production. Wherever this water is likely to have a long lifetime, it could be a useful emission-free energy resource as direct-use geothermal.

Electricity Generation

The highest temperature geothermal resources are used to generate electricity. There are three basic types

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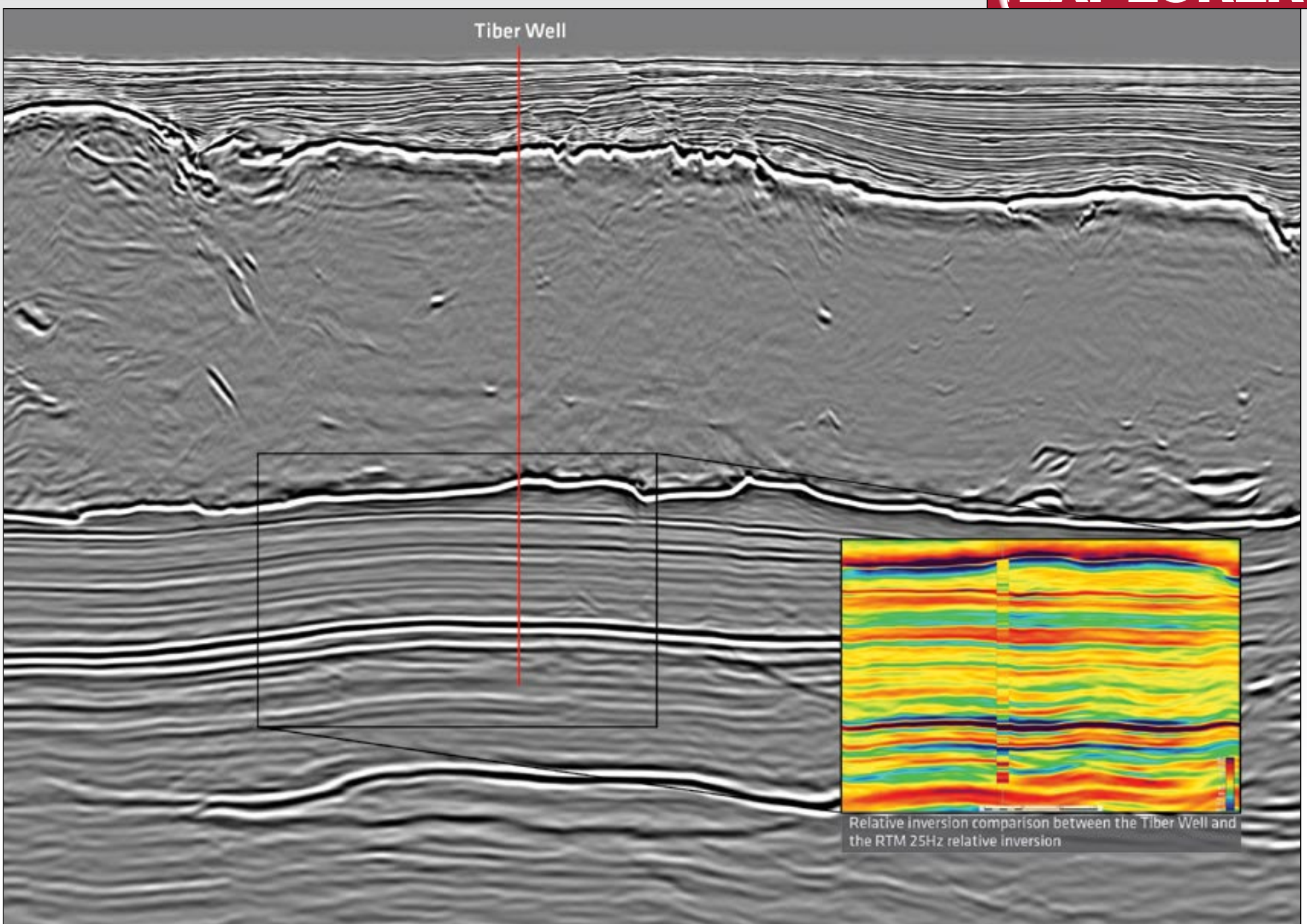

Relative inversion comparison between the Tiber Well and the RTM 25Hz relative inversion