

AAPG EXPLORER

February 2021



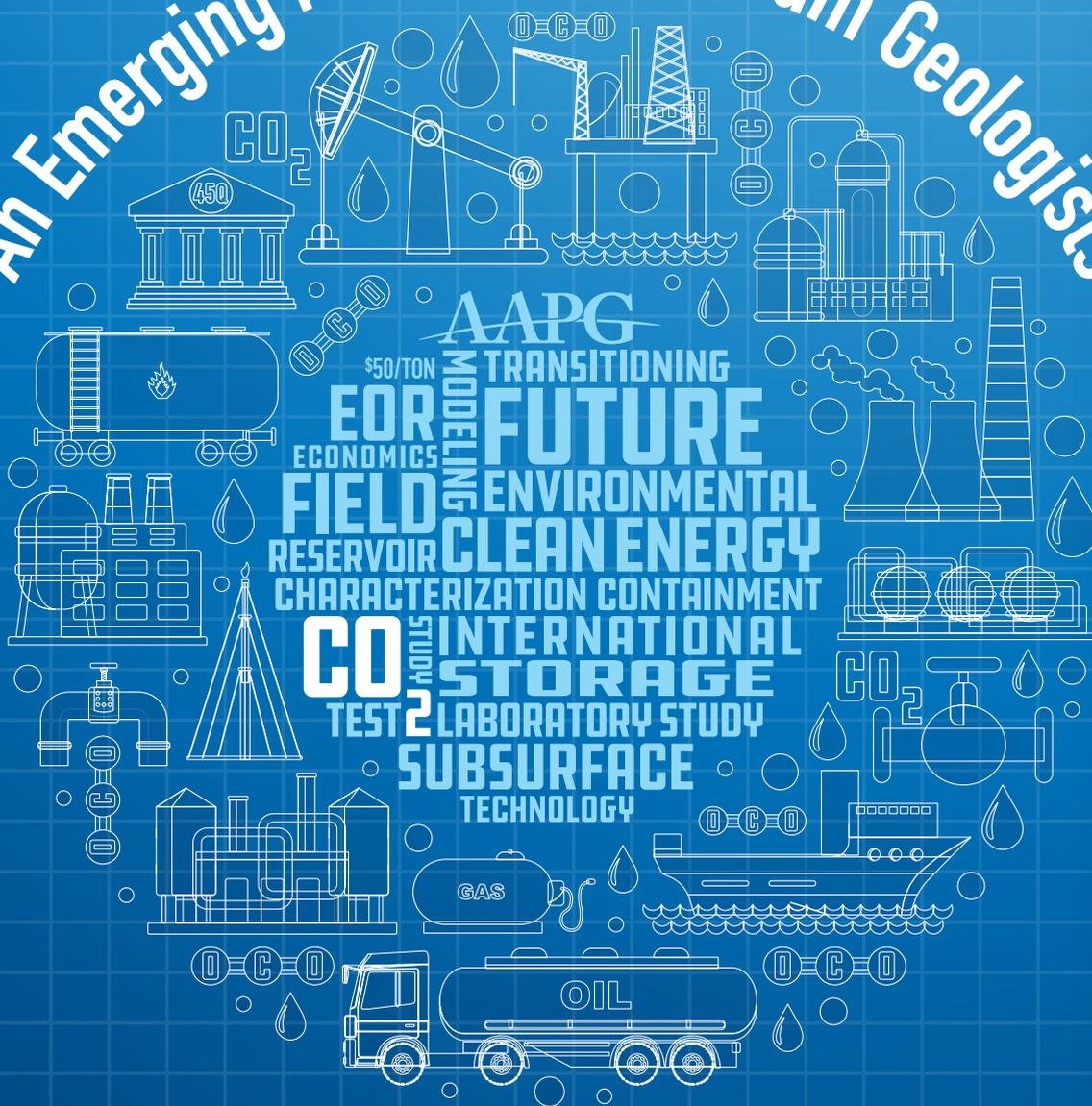
Bonanza in the Andes

See page 20.



23–24 March 2021 • Sugar Land, TX

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Plan now to attend AAPG's Carbon Capture, Utilization, and Storage (CCUS) Conference 23–24 March 2021. Themed "An Emerging Field for Petroleum Geologists," the conference will highlight current CCUS work and tackle related challenges including subsurface storage in saline reservoirs, storage associated with CO₂ enhanced oil recovery, reservoir monitoring and risk assessment, case studies, industry applications, economics, incentives, policies and regulations, and more.

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Predicting the Future and How it Impacts AAPG

President's Column

I went to a talk years ago by a speaker who was introduced as a "futurist" for his ability to predict. I've always wanted the title of "futurist," but I've not earned it. I've been reading a lot of predictions for 2021 from various magazines, papers and blogs. Now I'm as close to a futurist as I will ever get, so here are a few predictions from the experts (I agree with) and how they may impact AAPG.

The best way to predict the future is to create it.

in 2021 although they may be fundamentally different. AAPG relies on sponsorship support from companies and we look forward to their success in this new environment.

COVID-19 Virus

The pandemic has had a devastating effect on the world. Our thoughts and prayers are continually with those who are sick and especially with those who have lost loved ones. Right now there seems to be some optimism tied to coronavirus vaccines and herd immunity. I heard on the news that there are a total 45 different vaccines in development around the world. Of course, distribution of the vaccines is a key concern. AAPG leadership and staff are paying particular attention to vaccine distribution plus state and city COVID-19 rules as we prepare for a face-to-face AAPG Annual Convention and Exhibition in Denver, May 23-26, 2021. We are continuing to evaluate the situation day-by-day. Keep tuned.

Economics

Most likely, the world will have a mixed economic recovery in 2021. World economics are tied closely to the success of vaccines, so it will vary from country to country. Governments will pivot from helping workers who have lost their jobs to keeping companies from failing. Inflation will increase as much as 2 percent (or more) from all the money governments are printing for protection programs. Nevertheless, there is a sense that economies are recovering. China is experiencing a stronger than expected recovery and this impacts world economics. If the COVID-19 virus is finally brought under control, some economists expect global GDP

to grow as much as 5+ percent.

AAPG has made major spending cuts to respond to the loss of its economic engine – that being face-to-face meetings – and the consolidation of the oil and gas industry. We are getting closer to balancing the budget, but we are on a knife's edge, economically. Several of our major non-operated revenue sources, such as NAPE and OTC, were moved to the summer of 2021, so we are looking forward to an improving financial situation in the last half of this year.

Oil and Gas

The oil and gas industry will continue to be in a state of consolidation and evolution. Focus will be on innovation, best practices, well efficiency and cutting costs. Oil markets in

2021 will be dominated by demand recovery and by OPEC decisions on supply plus the recovery of U.S. production. Capital will be tight and companies will continue to keep CAPEX low. The mergers and acquisitions market is not expected to recover significantly. One obstacle to expect is a regulatory onslaught from frac'ing bans to new taxes for carbon and methane. The midstream sector will have difficulty building new pipelines.

What does all of this do to oil and gas productions and prices?

In the United States, most likely, oil imports will increase and gas exports will increase. As I am writing this column, oil prices are over \$50 per barrel, but how long will that last?

So how does this impact AAPG?

There is a lot of uncertainty, which is not good. Our hope is that companies will recover

Sustainability

As I mentioned in my January column, with all of the corporate 2050 zero-emission goals, it very clear that companies are changing their culture to emphasize the sustainable development of petroleum resources and other forms of energy. For companies this is a critical step for social license, continued investment and to attract quality talent. The world needs oil and gas well into the future, but it must be incorporated and enhanced with sustainable development and alternate energy. AAPG will change its culture to fit more closely to industry, but oil and gas will still be our primary focus. In addition, AAPG will focus on alternate energy through our Energy Minerals Division and the Sustainable Development Committee.

Environment and Emissions

Companies will increase focus on the impact of climate change to energy needs. Environmental, social and corporate governance factors will reach a tipping point and will be critical in obtaining capital. Banks and private equities will continue to expand investment into decarbonization. Carbon capture, utilization and storage will develop very slowly until there are more abundant, continuous sources of CO2 and sites for storage. CO2 utilization will attract a lot of investment into enhanced oil recovery projects. AAPG is actively developing and supporting the science and is holding its first major CCUS conference on March 23-25, 2021. There are a lot of jobs in environmental geology and the Division of Environmental

Pivot No. 6: Integrated Basin Analysis

During the 1990s, AAPG came out with a key special publication: Memoir No. 60, "The Petroleum System," edited by Les Magoon and Wally Dow. At the same time, I was working with Drs. Larry Meckel and J. T. Smith, both ex-Shell, on a huge regional Austin Chalk Study (which is still available). Integrated sedimentary basin analysis finally made a mark on me while working on this project. We were studying a big basin, the Gulf Coast. We mapped a very broad area of the chalk from Mexico to Florida.

During the study we realized methods to identify sweet spots in the Austin Chalk. These sweet spots were based on old log analysis and sub-regional fracture zones; they were typically 5,000 to 20,000 acres in size. Several of our clients loved the concept and were very successful in drilling horizontal wells in oil to condensate phase sweet spots. The funny thing is, a year later I noticed one large client was drilling poor wells between the sweet spots. When I asked them "Why?," they said that they were so successful on their first wells drilling sweet spots that they had to drill the intervening property. Oh well. So much for prediction!

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Humboldt State University geology students (from left) Wyeth Wunderlich, Olivia Helprin and Jared Walbert map the geology of the Ramuschaka Watershed. The community of Zurite lies on the other side of the clouds, approximately 1,000 meters below. Photo by Jasper Oshun. See story on page 20.

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Call for Papers

AAPG Bulletin Special Issue: Deep to Ultra-Deep Petroleum Systems

The global oil and gas industry is currently exploring new frontiers, including unconventional resources, deepwater offshore and deep to ultra-deep strata onshore. These represent a strategic shift in petroleum exploration. This call-for-papers is for an AAPG Bulletin's special issue focused on new research into deep basin reservoir formation mechanisms, hydrocarbon accumulation and preservation models. We are recruiting worldwide case studies and new technologies.

A significant breakthrough has been made in China and elsewhere exploring deeply buried reservoir plays in the past decade. There are several giant discoveries

deeper than 8,000 meters in western China, with commercial liquid hydrocarbons occurring below 8,200 meters in the Tarim Basin. Knowledge of hydrocarbon behavior and accumulation mechanisms in micro-nano pores, the influence of organic-inorganic interaction under extremely high pressure and temperature, and the distribution, assessment and prediction of hydrocarbon resources in these deep basins are advancing rapidly.

This special issue of the AAPG Bulletin aims to document all aspects of petroleum systems in deep to ultra-deep frontiers, including both clastic and carbonate (dolomite) plays in onshore and offshore

environments. Papers will showcase some latest discoveries in deep strata exploration worldwide and provide valuable insights and models for petroleum exploration in deep basins worldwide.

▶ On or before March 30, 2021, confirm interest in participation with title and authorship.

▶ June 30, 2021, preliminary manuscripts due.

▶ July-September, review process.

▶ Oct. 31, 2021, reviewers recommend edits.

▶ Nov. 23-24, 2021 AAPG "Ultra-deep petroleum systems" GTW organized by AAPG Center and the Deep Oil and Gas Laboratory

at China University of Petroleum, Qingdao, China. Authors will meet to discuss the special issue.

▶ Jan. 30, 2022 edited final manuscripts due.

▶ March 2022: AAPG Bulletin published.

For all inquiries, please contact the Special Editor of the AAPG Bulletin Special Issue: Professor Fang Hao, Fellow of Chinese Academy of Sciences and President of UPC and Prof. Keyu Liu, Academic Chair of the School of Geosciences, UPC, 66 Changjiang West Road, Huangdao District, Qingdao, Shandong Province 266580, China, liukeyu@upc.edu.cn. 

A joint publication of SEG and AAPG
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A journal of subsurface characterization



upcoming submission deadlines

Interpretation, copublished by SEG and AAPG, aims to advance the practice of subsurface interpretation.

SCHEDULED TOPICS

Visit <https://library.seg.org/page/inteio/Interpretation-special-sections> for more details about these sections.

MAY 2022

Recent Advances in Lacustrine Moderate-Low Maturity Shale Oil Exploration and Development

Submission deadline: 1 July 2021

Special-section editors: Min Wang, Shu Jiang, Tongwei Zhang, Zhejun Pan, Tim Carr, Zhuoheng Chen, Guochang Wang, and Chungqing Jiang

FEBRUARY 2022

Computational and analytical insights into stratigraphic processes and products

Submission deadline: 1 May 2021

Special-section editors: Fabien Laugier, R. Chadwick Holmes, and Lisa Stright



NOVEMBER 2021

Focus on Africa

Submission deadline: 20 January 2021

Special-section editors: Sunday O. Amoyedo, Abderrahim Lafram, Sanmi Tunde Emmanuel, Mike Oladapo, and Donatus Angnuureng

Geoscience of Hydraulic Fracturing

Submission deadline: 20 January 2021

Special-section editors: Ishank Gupta, Vikram Jayaram, Chandra Rai, Timothy Carr, Dengliang Gao, William Harbert, Ge Jin, Adam Haecker, Kyle Haustveit, Manika Prasad, Mirna Slim, Vishal Das, Srinivasa Reddy Karri, and Dongxiao Zhang

Russia: Recent Developments in Hydrocarbon Exploration and Production

Submission deadline: 20 January 2021

Special-section editors: Vsevolod Egorov, Olga Almendinger, Vladimir Verzhbitskiy, Anton Duchkov, J.T. (Han) van Gorsel, Igor Kerusov, Dmitry Modin, Boris Platov, Konstantin Osypov, Alexander Savitsky, Olga Shiganova, and Sergey Turuntaev

Distributed Acoustic Sensing (DAS)

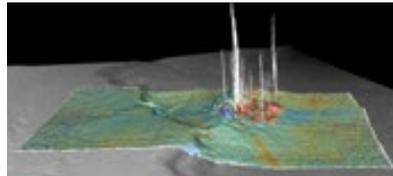
Submission deadline: 1 February 2021

Special-section editors: Ran Zhou, Konstantin Osypov, Hyoungsu Baek, Andrej Bona, Yingping Li, Roman Pevsner, Michel Verliac, Shuvajit Bhattacharya, Mark Willis, and Ge Zhan

Hydrocarbon Migration, Near-Surface Seepage, and Petroleum System Assessment

Submission deadline: 1 February 2021

Special-section editors: Jamshid "Jim" Gharib, Vsevolod Egorov, Michael Abrams, Harry Dembicki Jr., Roar Heggland, Benjamin Phrampus, and Jeffrey Beeson



Seismic amplitude interpretation for conventional and unconventional resources

Submission deadline: 1 February 2021

Special-section editors: Bo Zhang, Zhaoyun Zong, Jing Ba, Sanyi Yuan, and Sumit Verma

SUBMISSION DEADLINES PAST DUE:

AUGUST 2021

Benefits and challenges of depth versus time migration for impedance inversion

Submission deadline: 1 December 2020

Special-section editors: Arash JafarGandomi, Alexandro Vera-Arroyo, Mita Sengupta, and Alvaro F. Martini

The uplift of Himalaya-Tibet Plateau and its impacts on basin evolution and hydrocarbon accumulation in Asia

Submission deadline: 1 December 2020

Special-section editors: Shu Jiang, Dengfa He, Xiumian Hu, and Xiangyang Xie

Interpretation is a peer-reviewed journal copublished by SEG and AAPG to advance the practice of subsurface interpretation. Papers will be published online as they are accepted, edited, and composed, with issues printed quarterly in February, May, August, and November. Each issue contains at least one special section covering a topic of interest to interpreters. General submissions also are welcome in addition to submissions targeted to the topics above.

*E-mail interpretation@seg.org to inquire about submitting manuscripts past the submission deadline. Some sections may have increased flexibility regarding submission and review dates.

To submit a paper, visit <https://mc.manuscriptcentral.com/interpretation> and select the appropriate topic from the manuscript type options. For submissions not associated with a special section, select "Technical Paper."

President from previous page

Geoscience will play an increasing role in supporting this science.

Hybrid Work Model

Office life is changed forever. Virtual work from home will become a standard both for convenience and cost savings. We already see Zoom and similar programs evolving, and I predict there will be new software innovations in 2021 to make it even easier to communicate and work online. AAPG staff has worked virtually since March 2020 and they have not missed a step in providing services to members. One of the biggest questions facing the AAPG at the start of last year was whether or not to move its office to Houston. That seems a remote need at the moment as AAPG staff conduct work from all over the world.

Branding and Re-branding

Brands must be authentic, and value-driven. This is very important for AAPG as we figure out what our members need and want. Hopefully, we will get back to face-to-face meetings like geoscience technology workshops and the annual conferences, but we will continue to provide virtual programs. We need to be highly selective to provide value to members and non-members worldwide. Some companies will take this time to re-brand. AAPG is in the process of trying to understand what new products we need to provide to members, such as sustainable development and emissions science. We also are working to provide more opportunities through diversity, equality and inclusion programs. There is some call to change AAPG's name to reflect a broader energy science. You will have a voice in this as we survey members this spring.

That's enough on the future. I've run out of room. One thing I promise is that AAPG will not abandon its roots in the future. Oil and gas will be needed for decades to come. Just look at the amount of hydrocarbon-based energy it is taking to develop, test, re-test and distribute the vaccines. Transportation alone requires a huge fleet of planes, trains and trucks to distribute, not to mention the tons of dry ice required.

My primary hope for 2021 is that things get better and safer with more job opportunities.

A good friend reminded me that Abraham Lincoln said, "The best way to predict the future is to create it!"

Here we go!

Rick Fritz, Futurist

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The American Association of Petroleum Geologists (AAPG) and its Divisions, along with the Society for Sedimentary Geology (SEPM), are proud to host the AAPG 2021 Annual Convention & Exhibition (ACE) at the Colorado Convention Center in Denver, Colorado, 23-26 May 2021.

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A Seat at the Boardroom Table

Why geologists in leadership are good for business



Sylvia Anjos with a colleague



Robbie and colleagues on drillsite

Exploration is the heart of the oil and gas industry, and geologists are the heart of exploration.

Paradoxically, though geologists are among those most responsible for finding hydrocarbons, data collected by the Brazilian Association of Petroleum Geologists (ABGP) shows that geologists are less likely than their engineering and economist counterparts to be considered for leadership positions in the business and technology areas of oil and gas companies.

Sylvia Anjos, AAPG Member, past president of ABGP and business adviser at Petrobras, studied the data and said that companies would be wise to ensure that geologists are included on executive teams.

"Once large discoveries are made, there is a tendency to believe that the reserves are enough and to focus on production. Geologists are seen as not really critical. That is a mistake that is avoided when geologists hold leadership positions at companies," she said.

"Geologists value the odds of making new discoveries, so exploration remains a continuous, important process. I consider that this was one the reasons for Petrobras' success in deep and ultradeep waters," she added.

As a passionate geologist and a more than 30-year industry veteran, Anjos knows a lot about geology and about business.

Connecting the Puzzle Pieces

Anjos's interest in geology started at age six when her father showed her a world map.

"He told me that Brazil and Africa used to be connected, like a puzzle!" she said.

Her interest piqued again in middle school geography class when the teacher described the evolution and rise of the Andes and isolation of the Amazon Basin from the ocean. She was so fascinated that she decided to study geology.

After graduation, Anjos joined Petrobras, Brazil's national oil company, and she worked with a variety of technical projects and teams before moving into management. Over time, the pieces of her career started to fit together.

"It took me a long time, 20 years, to agree to go into management. The third offer I received was for a managerial

position with strong technical input, so I decided to try it," she said.

During her management career at Petrobras, Anjos and her colleagues experienced the opening of the E&P sector and worked on multiple fronts to be prepared for competition.

She currently serves as business adviser for Petrobras Downstream and is helping the company prepare for Brazil's transition into a new gas regulatory regime and open market.

Anjos said that geologists bring both the technical experience and the skillset needed to be effective in strategic positions.

"If a profession like geology can deal with huge amounts of intangible variables in nature and geological processes, imagine how easy it is for geologists to deal with the more realistic nature of business, as well as the intangible nature it can have sometimes," she said.

"During climate change discussions, geologists are the professionals that can provide the real approach to the problem. Because we are trained to see in 4-D, we value and position facts properly across time, geological time," Anjos added.

Opportunities for Team Players

Liz Schwarze, AAPG Member and vice president of Chevron's Global Exploration Group, said geologists' manner of thinking helps them adapt well to the business world.

"As geoscientists, we think in three dimensions, and I think that is quite helpful in the multifaceted challenges we face at

the reservoir level and even at the industry level," she said.

Schwarze found geoscience during her freshman year in college when two sorority sisters convinced her to take Geology 101. Before long, she was hooked and chose geology as her major.

"As an introverted science kid with a love for the outdoors, geology filled my soul," she said. "Studying the Earth requires all the sciences, and the curriculum included lots of field trips. The professors, graduate students and undergraduates all mingled easily as colleagues and friends."

Schwarze's love for community and interdisciplinary collaboration deepened during her early years at Chevron.

"About two years into my career, my group became the first cross-functional co-located team in our office. We were a pilot to see if working side by side with the other professionals needed to run an oil field would be better than working side-by-side with people in our function working different oil fields," she said.

The pilot was a success, and in addition to teaching her about cross-functional teams, the experience gave Schwarze the opportunity to develop a close working relationship with the group's reservoir engineer.

"He took me under his wing, so to speak, and taught me all about how reservoirs perform, how to forecast production and how to run economics. That helped me really understand the decision-making process," she said.

Schwarze enrolled in an MBA program and took classes at night while building her career at Chevron.



Susan Morrice and BNE employees

"From the beginning of my career, I was keen to collaborate cross-functionally and to have my team all rowing in the same direction. I learned on the job that I have strengths in building alignment, focusing on what matters and project management, and I leaned into those strengths to make the jump from a technical contributor career path to a leadership career path," she said.

As vice president of global exploration at Chevron she is responsible for the company's worldwide exploration program and chairs the company's Global Exploration Leadership Team. The position involves reviewing technical projects, a task she enjoys.

"I do get many opportunities to see technical work and offer my thoughts," she said. "It's a fun part of my job and I think above all else it helps me connect with people."

Geologists as Entrepreneurs

Robbie Gries, former AAPG president and president of Priority Oil and Gas, LLC, is proof that geologists not only make good company executives but also can excel as business owners and entrepreneurs.

The 45-year petroleum industry veteran found geology her sophomore year in college when she was looking for a science class with a highly recommended teacher.

"Someone suggested geology, and I said, 'What is that?' I had come from a tiny high school and had never heard the word. I fell in love, by the end of that year I had taken three courses and changed my major," she said.

Gries joined the industry and developed an interest in business while expanding the geographic and technical knowledge she needed to evaluate prospects and projects.

"I never intended to have my own business, but as I left larger companies and went to smaller companies, I learned other skills ... geophysics, engineering, lease acquisition, economics. Soon I was able to become 'independent,' and I started my own company when I had an opportunity to buy some producing properties," she said.

Gries has worked independently since 1980. She currently owns a natural gas production, petroleum exploration and

Continued on next page ►

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development company based in Denver.

Gries said geologists have unique strengths that help them to successfully run businesses.

"I believe we (geologists) are better at addressing the risk in a project, as we don't just use numbers; we have a studied approach to reservoirs and better intrinsic understanding of the scientific risks ... and the upside potential," she said.

Thinking Outside the Barrel

Susan Morrice, AAPG Member and founder and chairman of Belize Natural Energy, found both geology and entrepreneurship early in life. She grew up loving nature and outdoors while picnicking with her family on the rocks near their home in Ireland. She studied geology in college and shortly after graduation got a job conducting research in the United States.

"I found entrepreneurship was the backbone of the country, so I decided I'd better become one ... fast! I did just that within three years of graduation," she said.

Along with love for business, Morrice developed a passion for Belize, and she decided to start an energy company that made a sustainable difference in the country and its people.

She found a Belizian partner, and they struck oil on their first try. Morrice credits her success with studying the mind and mindsets and adopting a firm belief in AAPG founder Wallace Pratt's statement, "Oil is found in the mind."

The company Morrice founded, Belize Natural Energy, has been the No. 1 revenue generator in Belize for more than 12 years and has won multiple international awards for its holistic, sustainable business model.

Susan credits geologists' creativity and imagination with helping them to be successful in the business world.

"Geoscientists usually have nurtured their imagination. We never have all the data points, so we have to think outside the box – or barrel! – finding other value chains to increase the number of profit lines and not just rely on the price of the crude roller coaster," she said.

What Geologists Bring to the Table

Schwarze agreed that the ability to face uncertainty is an advantage geoscientists bring to executive teams.

"We all live with uncertainty, and I think geoscientists are generally more comfortable with it. We see that our industry faces ups and downs, and it is impossible to predict the future, whether that is at a macroeconomic scale or at a local field scale," she said.

"Things happen to disrupt our predictions of the future. In geoscience, we are forever striving to understand the rocks a little bit better. Taking that over to the financial side, we are more likely to have humility about our predictions, and I think that can give us an edge when it comes to adjusting to the downside or the upside."

Anjos cited three advantages that geoscientists bring to companies.

"Geologists have a knowledge of the petroleum systems, the audacity to question previous unsuccessful concepts and most importantly, a managerial sense of cost and reward," she said.

"When geologists aren't at the table, companies lose their unique ability to understand the uncertainties of nature, the exact value of geological risks and most of all, a profession that is trained to argue and to raise other hypotheses for the same subject!" she added.

Anjos has seen firsthand the financial benefits that come from having geologists on management teams.



"Geologists bring oil and gas companies a more effective sense of risk analysis. They know when the value of the prize compensates the risk of investment," she said.

Anjos noted how major discoveries in Brazil happened because Petrobras leadership made the difficult decision to go further after drilling dry wells first.

"The giant turbidites fields of Campos Basin and the supergiant fields of Pre-salt in Santos Basin are huge discoveries that happened when two excellent geologists were directors at Petrobras and made the right decision to go against the odds to make the discoveries," she said.

Strategies for Seating the Table

Schwarze said that diversity and inclusion – not only in professional discipline, but also in gender, background and experience – is a fundamental part of making companies' teams successful.

"Each and every one of us has a skill we brought to this industry and a myriad of experiences that form the core of how we react and make decisions. I call this our consequence history," she said.

"Every one of us is unique because we've had different childhoods, academic and work histories. So, if you exclude geoscientists or any specific group, you miss out on bringing that person's unique skill and consequence history to bear on the challenges at hand. So, when seating a table, casting the net wide matters."

Schwarze noted that diversity and inclusion is a high priority for Chevron, which has a series of programs and

platforms to promote diversity, inclusion learning and dialog.

"Our reputation and effectiveness depend on our diversity and inclusion efforts," she said.

She noted that, in addition to seeking diversity, businesses should have a vision for growth and continuity in their leadership teams.

"Companies need to take the long view in development, communicate clearly what it takes to be a senior leader and link sponsorship programs to succession-planning processes," she said.

Advice to the Next Generations

For Morrice, a key question for young people considering management is knowing whether their values align with their company's.

"Make sure the company is on the 'same page' and has the same values that you do ... Reflect on that journey within before anything," she said.

Anjos believes strongly that geoscientists should build a strong technical foundation before moving into management. Doing so will help them develop the skills they need to explore multiple hypotheses and make decisions, she said.

"In my experience, people who come into management too soon can focus more on administrative details or can be driven to make decisions before understanding all the options," she said. "This is not good for the long-term health of the company."

Schwarze noted that geoscientists

considering management should have a clear understanding of what it means to lead teams.

"Not everyone is a good manager, and you have to really like to set alignment and direct others, you have to achieve personal satisfaction through the work of others and you have to relish giving the recognition and praise to the team," she said.

She invited geoscientists entering the profession to conduct a series of self-assessments, both at the start and during the course of their careers.

"Identify your goals – life and professional. Identify the basic trade-offs you are willing to make. Identify your strengths and opportunities; leverage the strengths to new roles and close the opportunities through training, mentoring and practice," she said.

Gries noted that ongoing self-assessment also is important for geoscientists considering careers as business owners.

"Ask yourself, can you mentally handle uncertainty? Can you prepare for the ups and downs of business in the commodity world? That being said, if someone had asked me when I was 25 if I could handle that I would likely have said, 'no.' But in my 40s I started learning how resilient I was and what a powerful tool networking was ... this gave me confidence and tolerance for risk," she said.

Schwarze encouraged young employees to communicate actively with their companies when seeking to advance in their careers.

"Advocate for yourself," she said. "Make a clear case for your own abilities and ask a supervisor what it will take to get to the next level."

Gries encouraged self-improvement even when corporate support is not an option.

"Invest in yourself. Find areas where you can improve and pay for it yourself, take the time to do it even if your company won't support it," she said. "I took many classes outside of work to improve areas where I was weak."

Morrice encouraged young people to think big and dream bigger.

"Go way outside your comfort zone and find out what you are made of," she said. "Be all you can be and live the life of your dreams!"



Liz Schwarze speaking during an Offshore Technology panel in May 2019

Can Oil Explorers Dare to Hope in 2021?

As oil prices continued to rise in early 2021, explorers had to grapple with an unfamiliar and even somewhat bizarre possibility.

Is the business outlook for the oil and gas industry going to be better than almost anyone expected?

Not surprisingly, that idea met with an abundance of caution, and even skepticism, from an industry that experienced the severe downturn of 2014-16 followed by the worldwide COVID pandemic of 2020.

Still, "I think there's plenty to be excited about, especially given the recent upsurge in oil prices," said Alex Beeker, principal analyst, corporate analysis in New York City for international research and consultancy group Wood Mackenzie.

Supply Reduced, Demand Steady

Spot prices for West Texas Intermediate crude began to climb out of pandemic-induced lows in May 2020 but seemed stuck in a \$40-45 per barrel-range. Then, late in the year, prices rallied above \$50.

In the United States, Henry Hub natural gas prices spent the first half of 2020 below \$2 per million Btu, then rallied sharply in the second half of the year. However, those higher oil and gas prices did little except put operators back on their feet, Beeker observed.

"Capital is probably not going to be as available to these companies as it has been in the past, so they are going to be forced to live within cash flow," Beeker said.

"At \$50 a barrel WTI, companies are able to reinvest about 80 percent of their operating cash flow, pay down some debt, maybe pay a few dividends," he added.

But at \$50 a barrel "there's essentially no room for growth," Beeker noted.

"At \$60 a barrel that jumps quite a bit. It probably makes sense to add rigs to grow modestly, and 5 to 10 percent is a number that gets thrown around a lot," he said.

A decision by OPEC+ to hold production steady and a late-2020 commitment by Saudi Arabia to reduce oil production helped boost world oil prices, said Duane Dickson, vice chairman and U.S. oil, gas and chemicals leader for professional services and consulting firm Deloitte LLC in New York City.

The Saudi pledge to reduce supplies by 1 million barrels a day "has added to the stubbornness of bulls in the capital and commodities market," Dickson noted.

"However, the fundamental side of the equation, demand, is not budging much. For example, oil demand remained flat at around 92 million barrels a day in the fourth quarter of 2020 and it is likely to remain under pressure in the first half of 2021," he said.

Continuing constraints on oil consumption include new lockdowns in large parts of Europe, Dickson said. Road traffic in most parts of Europe dropped by 15-25 percent in early January, he noted.

Despite prospects for a slow recovery in energy demand rather than a resurgence, optimism emerged that the worst of the oil industry's layoff picture is in the past.

"I do think we're mostly out of the woods in that part of the equation," Beeker said.

But he predicted some additional layoffs could occur as companies try to minimize costs, increase efficiency and even build financial strength to take advantage of acquisition opportunities. Could a round of mergers and acquisitions-related layoffs happen in 2021?

"Unfortunately, possibly," Beeker said.

The tug-of-war between U.S. shale pro-

ducers and OPEC+ continued to dominate the industry's business outlook in early 2021, with Saudi Arabia still willing to curb production in hopes of stifling shale development.

"The risk is certainly asymmetric to the downside here. But putting on my optimist's hat, shale production is obviously a big part of this," Beeker said.

A stalemate seemed the most likely outcome, with OPEC+ extending production curtailments, U.S. shale producers hoping to avoid a price war and growth possibilities limited.

"We actually predict (U.S.) production declines in 2021, declining by about 400,000 barrels a day," Beeker said.

Despite recent increases in the active rig count, "we think you would have to add more rigs even for U.S. production to remain flat," he observed.

Dickson said "the greatest opportunities for U.S. shale companies lie in minimizing natural gas venting and flaring, electrification of fleet and oilfield operations, investing in water-management projects and signing green-power purchase agreements."

"Fortunately, the U.S. shale industry is living up to this new challenge," he observed.

Dickson said that in the fourth quarter of last year, the share of gross gas output flared in the Permian Basin plummeted to a modern shale-era record low of 1.6 percent compared to about 4 percent in 2018, according to estimates by Rystad Energy.

"You've got a solid decade or more of shale inventory in the United States," Beeker said, but he sees shale development growth reversing at some point in the future when "you're spending so much money just in reversing last year's decline that the U.S. can't grow production."

Years of underinvestment have evolved into a potentially serious issue for the industry. In its 2021 industry outlook, Deloitte noted that oil and gas enterprises overall would need to invest more than \$525 billion annually just to replace yearly consumption and offset natural field declines.

"Although underinvestment of many years poses risks to supply in the medium term, any near-term recovery in oil prices should be used to prioritize balance sheet strength over growth in the income statement, accelerate decarbonization and digitalization efforts, and capitalize on the next M and A wave" to reach divestment targets and streamline portfolios, he said.

Merger and Acquisition Trends

In terms of future merger and acquisition activity, there's a disproportionate ratio of sellers to buyers right now in the market but "most companies in a good position to do deals have already done them," Beeker noted.

However, with improving conditions, "I do think this results in more deals happening, now that we're seeing positive results," he added.

"In recent months, the companies helped the most have been those that have suffered most. They might have been seen as being on the brink, but they have now been given a lifeline," he said.

Companies well-positioned for growth include Pioneer Natural Resources, ConocoPhillips, Devon and Diamondback Energy, all of whom made significant acquisitions in 2020, Beeker said.

In January, Pioneer announced it had completed its previously announced acquisition of Permian Basin-focused Parsley Energy in a for-stock transaction valued at \$4.5 billion. Pioneer has been able to refinance some of Parsley's debt at more favorable terms.

"Basically, that's going to save Pioneer about \$100 million a year, just from refinancing that Parsley debt. That number is actually coming in better than expected," Beeker said.

Impacts from Energy Transition

Another unknown in the industry's longer-term business outlook is the future effect of the energy transition and government attempts to address climate change.

"The future of energy relies on and offers a range of decarbonization options, from adhering to foundational health, safety and environmental requirements, to reducing greenhouse-gas emissions per unit of production, to developing a new portfolio of low-carbon fuel mix and energy sources," Dickson said.

He predicted companies that "deploy and harness the benefits of lean capital and cost structures, dynamic portfolio modeling and risk-management processes, the future of work and greener operations will be best placed to navigate the evolving oil market situation."

"On the other hand, companies with strategies linked to market cycles, that track their progress against the usual performance levers – reserves, internal rates of return, operating expenses, etc. – and still follow the outdated 2014-15 downturn handbook, will likely remain behind in all oil-price scenarios," he said.

Proceed Carefully

Despite some optimistic signs, caution is still the rule in the oil and gas industry today. Operators have seen too many setbacks and negative trends in the past half-dozen years.

"One of our biggest takeaways, our biggest lessons from the past year, is that companies are going to be much more cautious than ever before," Beeker said.

He compared the current situation to the emerging industry optimism four years ago, which turned out to be more of a head-fake than a solid turnaround.

"We encountered this in 2017. It was sort of unfortunate timing, because the Permian Basin was just taking off," Beeker noted. "Companies have learned from the past, and they're going to be more cautious going forward." 



Devon Energy Center in Oklahoma City. Devon Energy is among those companies positioned for growth in 2021.

AAPG | BULLETIN

Like You've Never Seen Before



Start the new year off with upgraded access from the AAPG Bulletin. AAPG Member Access to the online AAPG Bulletin is moving to a new platform hosted by GeoScienceWorld. You will still be able to read and download all Bulletin articles, from 1917 to the current issue.

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The One Where Gilligan and Frankenstein Chase Goldilocks

Building 3-D reservoir characterizations for optimal business value

This is a summary of a paper to be published in the AAPG Bulletin, entitled "The battle of Frankenstein and Gilligan and the Law of Increasing Reservoir Complexification: what matters in 3-D reservoir characterization modeling?"

Here is the problem: your company is trying to assess the volume and producibility of oil in a newly discovered deepwater reservoir. Only a handful of wells exist in the new field, perhaps as few as three or five in a field miles across, and although the 3-D seismic is helpful, it cannot be used to accurately define the geometry and lithology of the reservoir at the production scale. Wells cost hundreds of millions of dollars each and a platform much more. Everything must be done optimally and correctly, or massive business losses could occur. Is there enough oil in the reservoir for production to be profitable? Can production rates be maintained, and for how long?

If you were the project manager, what would you do in such a situation? The growth and perhaps even the survival of your company is at stake. You are dealing with massive investments, and very little, but extremely costly data.

There are two general solutions to this problem.

Frankenstein's Model

First, and most obviously, you gather every possible expert to analyze the data, however limited it is, and give them ample time to evaluate it. Next, using interpretation, interpolation and simulation based on the available yet limited dataset, you build a 3-D reservoir characterization model. Finally, you proceed with dynamic and economic modeling and come up with the best business decision. This approach, which focuses on using what is known about the reservoir, creates a deterministic model, which is referred to here as a "Frankenstein" model.

The term "Frankenstein model" was coined by Mark Williams in 2004, then a consultant reservoir simulation engineer, who noted that building an intricate 3-D Earth model often violated timelines for major capital projects, sometimes "killing" its creator, as did Frankenstein's monster. Even still, the reservoir model could fail during flow simulation, resulting in the need to completely rebuild the earth model, which would take even more time, further slowing the progress of the project.

Additionally, lookback studies often showed that these carefully constructed models were simply wrong or significantly in error, regardless of the time and care spent in construction. Perhaps the reservoir was modeled as a sheet when in fact it was valley-confined. Perhaps the net sand volume of the reservoir was greatly different than the modeled volume. Perhaps the reservoir was more faulted than expected or contained wet fault compartments that could not be imaged in the 3-D seismic. Perhaps the permeability was much more heterogeneous than modeled.

The Gilligan Approach

If carefully modeling what is known about a reservoir isn't the correct approach, what else can be done? Another approach to addressing the problem is to model what is not known about the reservoir.

Instead of using limited information to create a single 3-D earth model, why not build a suite of earth models portraying every possible reservoir geometry and

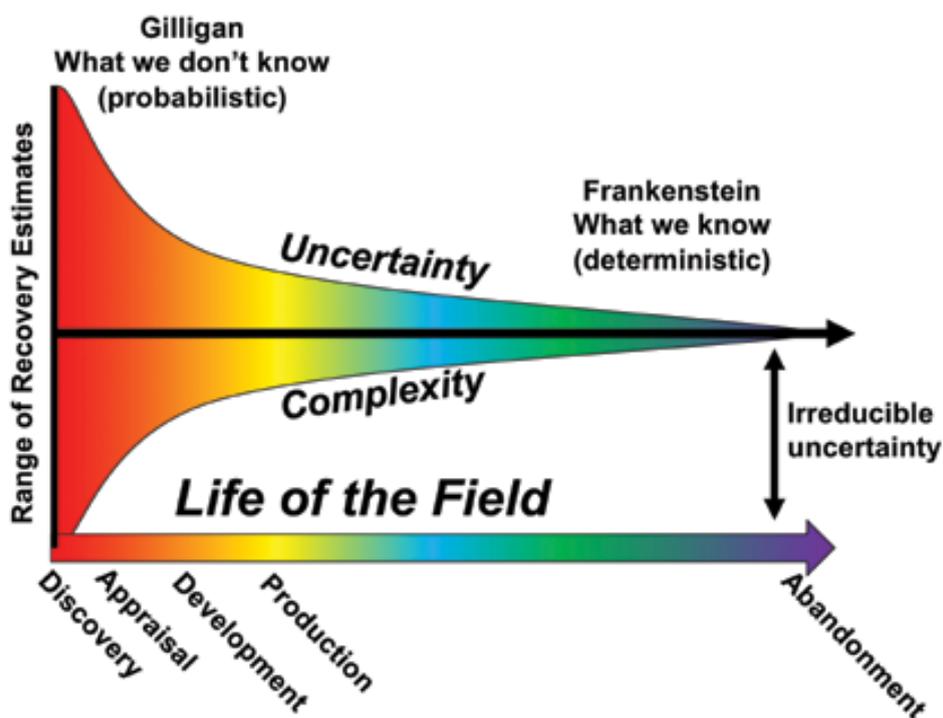


Figure 1: This is an adaptation of a figure by Arps that shows reduction in uncertainty as a field is developed. Uncertainty is lessened by drilling of new wells, re-interpreting seismic data and from production information. Uncertainty never goes to zero, as there are inherent uncertainties that are never completely eliminated. Here, it is noted that reservoir complexity increases with time. With added information as the field is developed and produced, new reservoir trends, faults, and geometries are identified. In general, the Gilligan approach has greatest value in cases of greatest uncertainty, whereas the Frankenstein approach, which doesn't address uncertainty, is more useful later in field life. However, because reservoir uncertainty is never completely minimized, the Gilligan approach can be useful in all stages of field development, even in ultra-mature fields.

architecture that might exist, effectively capturing uncertainty in reservoir character? Then, after building the models, use some quantitative wizardry to assign probabilities to each potential outcome. That is, using what is known about the reservoir as conditioning information, define and characterize what is not known about the reservoir: model what could be there, what might be there.

This modeling approach is considered probabilistic, and the models are called "Gilligan" models. I created the term "Gilligan models," also around 2004, to

represent the opposite of the Frankenstein approach. The creation of simple models might seem moronic to the Frankenstein modeler, who focuses on a super-detailed workflow. Oddly enough, the Gilligan approach can be done more quickly than the Frankenstein, because it creates a variety of simple solutions, though uses available conditioning data as well. An additional benefit of Gilligan modeling is that it presents testable scenarios. If the uncertainty is, for example, whether the reservoir is sheet-like or valley-confined, and if this difference is of economic

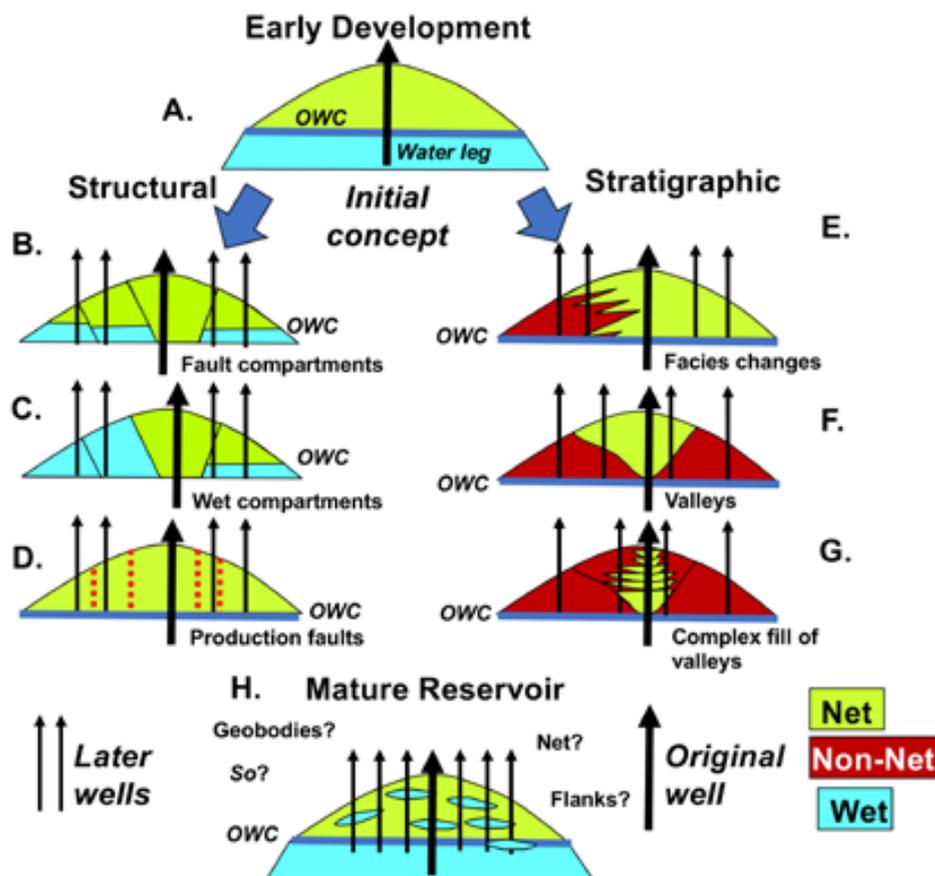


Figure 2: The Law of Reservoir Complexification. As reservoirs are developed and produced, additional data are provided, and the reservoir typically becomes more complex. Structural complications include defining new fault compartments, wet fault compartments and production faults (faults defined based on production data). From a stratigraphic standpoint, as wells are drilled, facies changes are better characterized, and geobody shapes are characterized and refined. Finally, for more mature reservoirs, heterogeneous fluid bodies may occur, such as water lenses from water injection in a waterflood.

significance, then management might be prompted to consider drilling an additional well or wells to address this uncertainty. The Gilligan workflow naturally leads to management of uncertainty. Frankenstein models do not characterize or address uncertainty, at least not directly.

Reservoirs Are Understood Backwards

To summarize, there are two end-member ways to characterize a reservoir in 3-D. The Frankenstein approach builds a model based on what is known about the reservoir. The Frankenstein approach addresses uncertainty using powerful interpretation, interpolation and simulation techniques to achieve what is believed to be, or hoped to be, the best and most correct answer. The Gilligan approach builds a model, or suite of models, based on what is not known about the reservoir. The Gilligan approach creates a spectrum of possible interpretations that can be further tested or used as possible outcomes.

The example discussed here has focused on the issue of deepwater fields, with very sparse wells, limited seismic data quality and enormous costs.

Can this concept of Frankenstein and Gilligan be applied to other new discoveries, other business situations, or even mature fields?

Let's ask the question another way: Are there surprises in development or production geology?

Surprises are a manifestation of uncertainty. Unexpected results are surprising. If there was a fully developed uncertainty model that existed prior to drilling a well, surprises would be reduced to confirmation of specific cases. Surprises occur at scales from drilling a single horizontal well, to drilling well patterns, to full field reservoir management, to frac'ing patterns in a tight well, to bidding on a property. In each of these cases, reservoir uncertainty is present at levels that could significantly impact economic or business decisions. In each of these situations, the role of uncertainty and how it impacts business value must be addressed. Building a single deterministic "Frankenstein" model may lead to a non-optimal business result, especially in light of uncertainty.

Kierkegaard wrote, "Life can only be understood backwards; but it must be lived forwards." You can replace "life" with "reservoirs."

Essentially, all reservoirs are characterized by uncertainty, even if they have been produced for a hundred years. Consider the fact that wells are spaced from hundreds to thousands of feet apart, wellbores are only inches wide, core is taken relatively sparsely, well logs are subject to all sorts of interpretation issues and seismic data can never resolve reservoir properties at the well log scale. Even the most mature reservoirs are sparsely sampled. To illustrate the issue of uncertainty in ultra-mature reservoirs, typical important uncertainties in such reservoirs are: 3-D distribution and definition of saturation, distribution of saturated geobodies, and even the distribution and definition of net sand. The science of reservoir characterization is taking the limited information we have, from wells, seismic and production, and creating a 3-D model using interpretation,

Beyond Exploration

How geoscientists can make a financial impact in a variety of company roles

A APG members throughout the world are proving that geologists can be highly beneficial to the oil and gas companies that employ them in areas beyond just exploration alone.

Two of them are Karyna Rodriguez, vice president of global new ventures at Searcher in London, and Eduardo Vallejo, program lead of technologies and subsurface knowledge at YPF Tecnología (Y-TEC) in Buenos Aires.

In interviews with the EXPLORER, both shared stories about their careers and provided advice to the next generation of professionals.

Finding Her Place

Rodriguez developed an interest in the physical world at an early age.

Geology was not offered at her grade school in Mexico and England, but she studied geography and developed a great interest in the physical world. When deciding what to study at university, she used a careers handbook to search for her favorite subject.

"For geography it listed teaching as the most likely job prospect and as I came from a family of teachers, I wanted to do something different," she said.

"When I turned over the page I came across geology. I was sold from beginning to end of the description. Studying the history of the Earth, outdoor fieldtrips, the opportunity to travel and, last but not least, the prospect of working in the oil industry – all resonated very strongly with me," she said.

Rodriguez decided to pursue a career in the oil and gas business, and she prepared by obtaining bachelor's and master's degrees in geology at Oxford University and a master's in stratigraphy from University College London.

She worked for companies in Europe and Mexico before assuming her current role at Searcher.

Her current primary responsibilities involve identifying, pursuing and realizing new multicient projects that optimize exploration for oil and gas in mature and frontier basins around the globe.

Rodriguez says she enjoys having the opportunity to generate projects that can help make hydrocarbon exploration and development more efficient.

"There is enormous satisfaction when a project comes to fruition and starts to deliver as expected," she said.

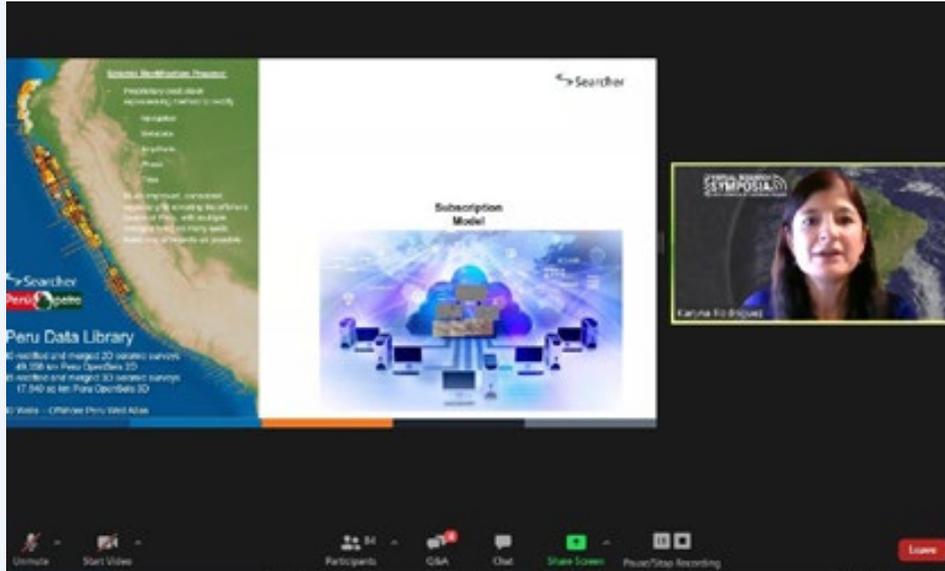
"I also like the relationship-building aspect, which is one of the key aspects to a successful project. This involves establishing and maintaining a good working relationship with governments, oil company clients, partners and of course, the Searcher team," she added.

The Geology Rebel

Like Rodriguez, Eduardo Vallejo discovered geology through his love of nature and desire to distinguish himself from family members.

Growing up in a family of lawyers in Tucumán, Argentina, Vallejo found an early interest in volcanoes and other natural phenomena.

When choosing higher studies, his father pressured him to go into law, but Vallejo resisted.



Karyna Rodriguez, vice president of global new ventures for London-based Searcher, presenting her company's projects and geological insights gained from the seismic and well data offshore Peru at the AAPG Pacific Virtual Basins Research Symposium, October 2020

"My 'rebellious' response was to study physics, but before I finished the first year, I thought it was too abstract for me. I had some friends studying natural science, so I decided to study geology instead, and that's when I found my calling," he said.

Vallejo received his degree in geology from the National University of Tucumán. While a student, he started working in research with a scholarship from Argentina's National Council for Scientific and Technical Research (CONICET).

Shortly after graduation, he learned of the opportunity to pursue a graduate program that culminated with a job at YPF, Argentina's national oil company.

"The opportunity to work in YPF, a pioneer in oil and gas, in an environment where technology holds a central role, along with having the chance to be independent and get to know other parts of the country – all this led me to the hydrocarbon sector," he said.

Once joining the industry, Vallejo never looked back. He said he has many reasons he likes working in the industry.

"I enjoy the complexity, the multidisciplinary approach, the challenges of oil and gas and energy in general, the opportunity to work as a team, applying cutting-edge technologies, the opportunities to experience different work environments, learn about other cultures and other geological environments," he said.

Not All About the Technical Side

Rodriguez echoed Vallejo's sentiments and noted that she appreciates how working in the industry allows her to learn and contribute in many ways.

"What I have enjoyed most about

working in the business is that my job has always had a strong technical aspect requiring creativity and innovation and with continuous opportunities to learn from the different disciplines involved in the exploration cycle," she said. "But it's not all about the technical side, and I have also enjoyed the challenge of reconciling geology with the financial and political aspects of the business."

Rodriguez noted how her role in new ventures allows her to inform the company's financial decisions.

"There are no decisions made at Searcher which do not consider the geological aspect of a project," she said. "There is no point in acquiring a large amount of data to fill in gaps if the geological indications are negative, as this could end up with the company having invested a large amount of capital in a project which will not sell and will not contribute positively towards oil and gas exploration."

She also noted that geological insights developed while working on different projects at Searcher can lead to the identification of areas with potential prospectivity that were previously overlooked, giving the company the opportunity to generate unique and valuable projects.

How Geologists Contribute

Vallejo said his experience and that of colleagues has shown that geologists can add value to the energy business in a variety of areas.

"Though the traditional roles are exploration and development, there are many others, from technical positions like

technology development, laboratory analysis and technical consulting to management positions in areas not directly related to the geology, including reserves auditing, strategy, sales, project evaluation and management," he said.

Vallejo noted how geologists' training helps them to develop abilities that enable them to perform well in different types of positions.

"One of those abilities is curiosity, which helps us understand what we cannot see directly and to deconstruct, crumble, analyze elements to understand and assemble models. Another is our analytic methodology, which helps us to understand and connect elements in stages to reduce risk and reach successful results. Also, something that characterizes us is that we are used to taking and managing risks, and this is very important in many activities," he said.

Vallejo uses all three of these abilities in his current position at Y-TEC, where he helps to define and consolidate the company's strategy for R&D project development and specialized technological services for the industry. Vallejo leads technical relations with clients and works in other areas, including technology surveillance, intellectual property protection and technology transfer and licensing processes.

Vallejo said he enjoys a position that includes both a technical and a business focus.

"I like being able to work both with Y-TEC and with businesses to align the portfolio of subsurface R&D projects to the needs and challenges of the E&P areas to develop and transfer valuable technological solutions on a commercial scale," he said. "I enjoy working to ensure that both the portfolio and the projects always have a comprehensive look and approach."

Career Opportunities

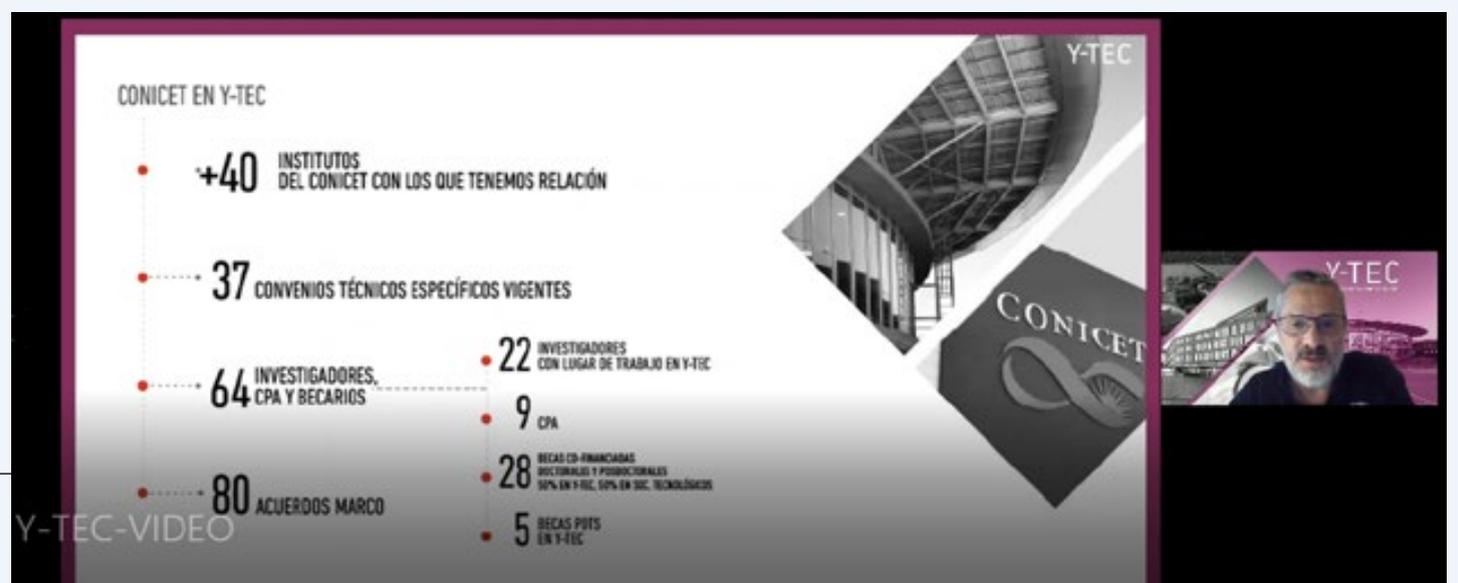
Vallejo noted that geologists who are interested in technology have many opportunities at companies during the energy transition.

"In new energies and (enhanced oil recovery), we need geologists to characterize and model reservoirs for projects related to fluid injection (H₂, CO₂), and they also are important for carbon capture, use and storage projects," he said.

He noted that working in technology provides a myriad of opportunities to support both traditional oil and gas projects as well as alternative energy exploration and development.

"Geoscientists have opportunities as technicians, not only developing solutions

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Eduardo Vallejo, program lead for technologies and subsurface knowledge for Buenos Aires-based YPF Tecnología, presenting Y-TEC's liaison model at an online conference in 2020.



Gathering the data set for subsurface data from Texas, US and Canadian Wells



Inside a geothermal plant. Photo by B. Cutright

The Heat Beneath our Feet

Harnessing geothermal energy

On the island of Nevis in the Caribbean, its 11,000 residents are on the verge of an energy transformation. In about two years, their cost of electricity will no longer fluctuate with market prices, and not even a hurricane will stop it from flowing. In fact, over a 25-year period, residents will save an estimated \$100 million in energy costs, based on today's pricing.

This is because in late 2022, this island in the Lesser Antilles will bid farewell to diesel, which it has imported for more than five decades to power its electrical grid, taking huge bites out of its gross domestic product.

Severing its ties with fossil fuel power generation will also reduce Nevis' carbon footprint and, it is hoped, lead the way for similar transitions all over the world.

How is this possible?

It is the result of a strategic conversion to geothermal energy developed by GeoFrame Energy, a newly created partnership between Schlumberger New Energy, AAPG Member Bruce Cutright and business partner Dan Pfeffer. Their goal is to make geothermal energy the most cost-effective and reliable means for providing clean, sustainable power. They are beginning in Nevis, with plans for similar projects in the Caribbean, the United States and North and South America.

Cutright has 35 years of experience in the oil and gas industry and serves as the chair of AAPG's Energy Minerals Division's Geothermal Group. He urges oil and gas professionals to look at the industry in a broader scope.

"Everyone is bemoaning the fact that the petroleum industry is slowing down. The economy is part of the reason, but there's also the feeling that it is a great contributor to climate change. Whether or not that is true, we have to follow where society is leading," he said. "AAPG is a petroleum organization. But younger members are seeing it in the broader

"Petroleum will always be important. We're not leaving it behind. But we need to think as energy professionals. This is within the areas of expertise of our members and has the capacity of changing the world."

context as an energy organization. We have the science and engineering capacities to identify high heat flow areas and productive reservoirs, so why aren't we doing that?"

Texas alone has the potential for supplying all of the United States' energy needs for 700 years with geothermal energy, Cutright said, citing a 2019 GeoVision report entitled, "Harnessing the Heat Beneath Our Feet," published by the U.S. Department of Energy.

The United States has the ability to increase geothermal power generation 10- to 20-fold by 2050, producing 50 gigawatts of electricity from geothermal sources, the report states. Furthermore, the International Geothermal Association expects worldwide geothermal generating capacity to double in the next 15 to 20 years and to continue growing.

Silver and Brine

As a former senior research associate at the Bureau of Economic Geology at the University of Texas at Austin, Cutright worked for the State of Texas Advanced Resource Recovery program, helping oil and gas companies improve production of existing resources. For every dollar funded by the state, Cutright and his team returned \$32 to \$38, generating roughly \$500 million in

severance tax value for the state. The key to that success was understanding geophysics and drilling technologies, he said.

That work piqued his interest in geothermal energy, knowing that the water cut, or brines, was always considered a waste product.

"But these brines are hot, and the heat represents an energy source all by itself," he said.

"Back in western Nevada in the 1800s when everyone was looking for gold, they found that it was wrapped in a grey mineral that was regarded as waste until someone figured out it was silver," he said, referencing the birth of Silver City.

With funding from the U.S. Department of Energy, Cutright developed the Texas Geothermal Resource Group at the BEG in 2010, and four years later formed his own company, Thermal Energy Partners, with Pfeffer. He left the BEG in 2016 to run the company full-time as interest in geothermal energy grew.

"Petroleum geologists can make a difference in developing geothermal energy simply by doing what we are very good at," Cutright said. "Brines are a valuable resource, and with the applicable technology we can produce renewable, sustainable energy at competitive market rates."

A 2006 report titled, "The Future of Geothermal Energy," from the Massachusetts Institute of Technology, estimated that the United States could produce 2,000 times the annual domestic energy demand from geothermal sources, providing renewable

energy sustainably for centuries.

Although the United States is the largest producer of geothermal energy today, Cutright's sentiments echo the report, which states, "In spite of its enormous potential, the geothermal option for the United States has been largely ignored."

Leveraging Oil and Gas Data

Texas has more than 1.4 million oil, gas and exploration wells that provide information on deep formation properties and formation temperatures. The United States has in excess of 4.5 million wells that provide similar information. These, along with supporting geologic studies, form the essential basics of geothermal exploration.

Yet renovating oil and gas wells to harness geothermal energy might not be ideal, Cutright determined. Many are simply too small in diameter to produce the flow rates necessary for useful geothermal power generation.

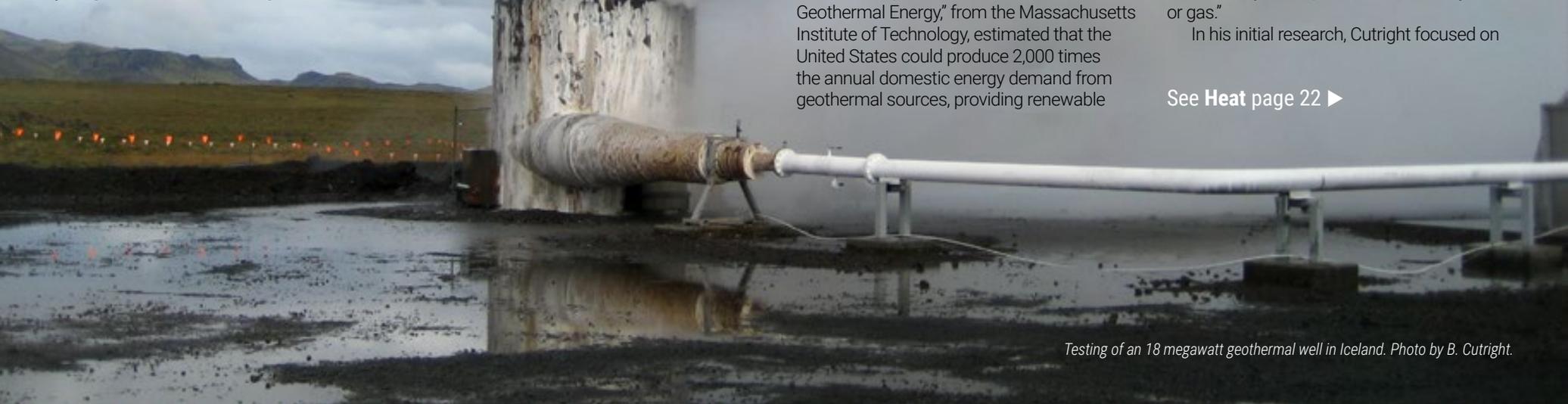
Although renovating an oil or gas well might typically cost 50 or 60 percent less than drilling a new well, Cutright concluded that because of too many unknowns, "it made more sense to have a purpose-designed well to produce geothermal fluids." In fact, wells drilled specifically to produce geothermal water and steam can yield nearly double the produced energy than renovated oil and gas wells.

Geothermal wells are designed to produce fluids from the full thickness of a producing formation.

"We are not worried about intervening clay layers. We can perforate the entire formation because we want to maximize fluid flow to that well," Cutright explained. "We as petroleum professionals have to understand efficient ways to capture hot fluids, not just oil or gas."

In his initial research, Cutright focused on

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Testing of an 18 megawatt geothermal well in Iceland. Photo by B. Cutright.

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with direct application in processes or operations directly related to our discipline, but also participating in the development of equipment, tools, chemicals, materials and software," he said.

Rodriguez agreed, and noted that the emerging field of artificial intelligence is another area where geoscientists can also make a financial impact.

"Any progress made towards reducing the exploration cycle time will reduce costs" she said. "AI is already changing the way we access seismic data, making seismic investment dollars go further, and enhancing the efficiency of gaining insight into any hydrocarbon basin."

Rodriguez sees the AI at work when using Searcher's "sAlismic" web-based platform, which provides on-the-spot seismic data access from large datasets stored in the cloud. Geologists at the company develop machine learning algorithms that to identify key geological features in the large amounts of data.

"We can use AI to automate some of the repetitive tasks and leave more time for geoscientists to analyze the results, which is where the real value is generated," she said.

Advice to Young Geoscientists

For Vallejo and Rodriguez, young geologists who are interested in the business side of oil and gas have many career options.

"There are no limits," Vallejo said, adding that young people should look for opportunities and be ready to seize them when the time comes.

"I always suggest that young geologists

complement their training with other knowledge, so that they can interact and understand other disciplines," he said. "That perhaps is a preliminary step, working as a geologist and understanding the business brings experience to later play other roles."

Rodriguez noted that oil and gas will continue to be the main source of energy for decades to come, and that the financial side of the business is an important part of it.

"I think that one of the main rewards in the future will be to watch countries in southeast Asia and Africa come out of poverty as they get more access to energy," she said.

"From my point of view, the business side of oil and gas is complicated, challenging, fascinating and very rewarding. I would say to any geoscientist who would like the challenge to unravel geopolitics, learn about and integrate financial aspects while at the same time continuing to apply geological science, this is the job for them," she added.

Hope for the Future

Rodriguez recognizes that, while it isn't always easy to work in the oil and gas industry, she is convinced that she made the right career choice.

"I joined the industry when oil was \$10 a barrel. I had just left university, sent over 200 CVs and did not get a single reply. I got my first technical assistant temporary job through a temping agency. As soon as I started the job, I immediately confirmed that this was where I wanted to build my career," she said.

"The ride has been bumpy with many ups and downs but the rewards have always outweighed the difficult times. Geology has been the fuel that has kept me going and I am so grateful that I turned the page on that careers handbook, as that marked the beginning of the best journey of my life." 

Goldilocks from page 10

interpolation and simulation. The role of uncertainty in reservoir characterization should never be taken lightly or assumed to be inconsequential.

"The only certainty is that nothing is certain," wrote Pliny the Elder.

Uncertainty is pervasive in all reservoirs, though reservoir uncertainty clearly decreases with production of the reservoir, added wells and improved seismic quality (Figure 1). The role of reservoir characterization in the oil and gas industry is always dealing with the relationship of what we know and what we don't know, and how that impacts business decisions. There is always a decision involved with regard to whether a deterministic approach or a probabilistic approach is preferable to address the economic issue at hand. In general, uncertainty should always be included in a study of reservoir character.

Increasing Complexity

Another interesting feature of oil and gas reservoirs that should be acknowledged in reservoir characterization studies is that reservoirs tend to become more complex as information is provided by drilling additional wells and through production. This is referred to here as the "law of increasing reservoir complexification." That is, a 3-D

earth model built for an exploration play, or for early development, will likely not be useful as the reservoir is developed, more wells are drilled, reservoir trends are established and quantified and new faults are found. The Frankenstein approach cannot be valid in the case of increasing complexification.

To summarize, sometimes the Frankenstein approach is better, sometimes the Gilligan but the difference lies in the nature of the business problem. If uncertainty is the main business focus, then the Gilligan approach is clearly superior. If group discussion and visualization is the main business focus, or reservoir uncertainty is considered minimal, then the Frankenstein approach might be more useful.

Finding the correct solution to the business problem is commonly referred to as the "Goldilocks approach," and usually Goldilocks is present somewhere between Frankenstein and Gilligan. But more fundamentally, the goal of 3-D earth modeling and reservoir characterization is always to add value to a business decision. In some cases, building a highly deterministic model adds value. In most cases, however, the characterization and quantification of uncertainty has the greatest economic value, for all reservoirs. If your company or business unit relies on Frankenstein 3-D earth models, consideration of the Gilligan approach would likely add value, on every reservoir, from appraisal to ultra-mature, from the spotting an individual well to full-field management. 



Dave Larue earned his doctorate in geology under Laurence Sloss at Northwestern University, then became an assistant professor at Stanford University, then a professor at the University of Puerto Rico. He worked for Exxon Production Research as a senior geology researcher, then worked for Chevron in sequence stratigraphy and modeling, then as a consulting geologist for oil field development in the San Joaquin Valley.



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Geophysical Corner

Low Frequency Land Seismic Data Acquisition

1 hertz or 2, what's the difference?

For many years the geophysical industry has spent considerable time and effort on improving the high-frequency content of recorded seismic data in the pursuit of higher resolution. However, in the last two decades we have seen an increased interest in extending the bandwidth of our data toward lower frequencies as well.

In this series of two articles, I will address the reasons we need low-frequency information, the issues related to its acquisition for onshore projects and discuss the equipment and methods being used.

Obviously, in order to be able to record low-frequency reflections, we need to be able to generate adequate signal strength in the desired low frequency range. This should be such that, after transmission through the Earth, we still have sufficient energy to be able to record signals that are not completely buried in noise – either ambient noise or the electronic noise from the recording sensors and instruments. The sensors themselves need to have adequate sensitivity in the frequency range needed.

An extremely important factor to note when discussing the bandwidth of seismic data is that we need to think in terms of octaves rather than in terms of hertz (or cycles per second, as we used to call them). When asked what low frequencies are wanted, many geologists or geophysicists will say “Oh, 1 or 2 hertz.” If we think in terms of hertz, this does not seem to be a very significant difference, but 1 to 2 hertz is a complete octave. There is often a substantial increase in data acquisition cost that results from acquiring this additional octave.

In this first article, we will review the reasons we need low frequencies, the signal transmission, the sensors used to receive the reflected signals and the recording instruments themselves. In next month's article we will assess the differences between using explosives versus vibrators and the advantages and disadvantages of each.

Discussion

There are four primary reasons commonly stated for acquiring lower frequency data.

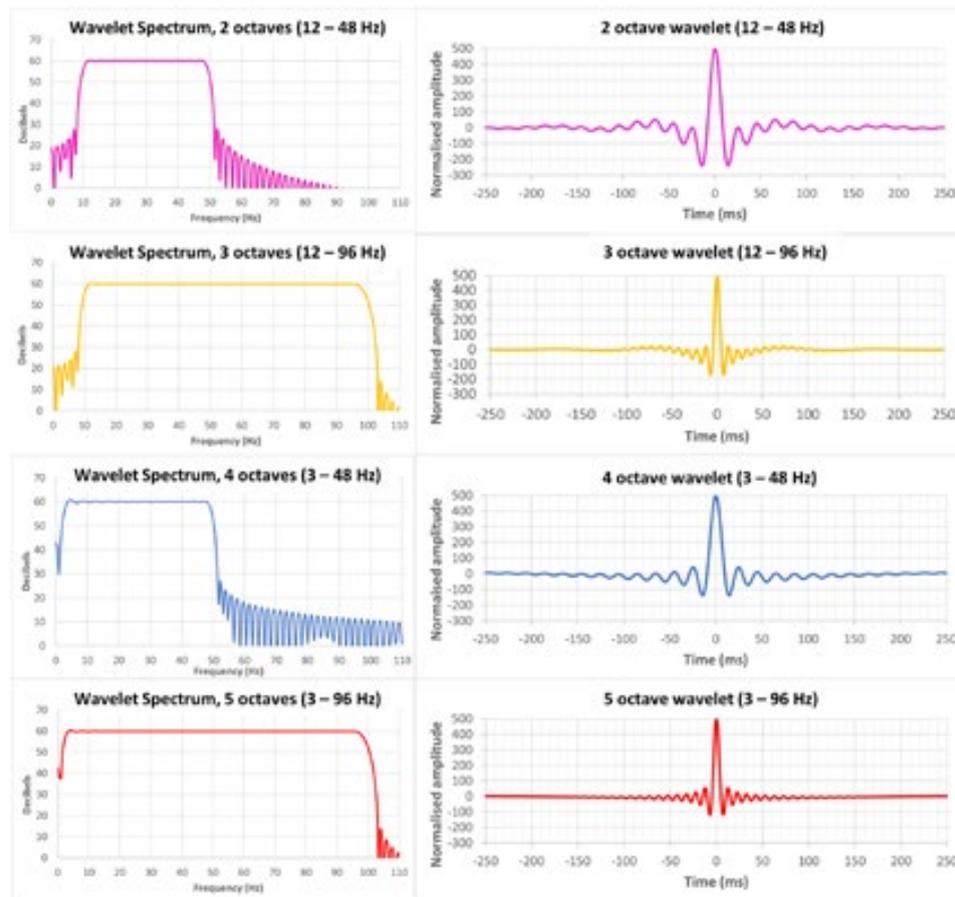


Figure 1: Wavelet design spectra and corresponding wavelets.

The first is that it will provide higher resolution and more “character” to the processed seismic images. The second is that when low frequencies are missing, any form of seismic inversion is less stable than when they are present. The third is that they are extremely important in the development of accurate velocity/depth models needed for modern high accuracy pre-stack depth migration algorithms. The last is that in regions with sub-coal, sub-salt or sub-basalt reservoirs, the low frequencies are necessary to provide the penetration required through the strong acoustic impedance contrasts.

Figure 1 shows four different signal wavelets with different octave ranges, and

therefore different frequency ranges. The uppermost wavelet has 2 octaves and it is apparent that the level of the sidelobes of the wavelet are quite high relative to the central peak. The second image shows the addition of 1 octave of higher frequencies. The central lobe is clearly much narrower, as is expected, and will directly provide higher resolution in the data. However, the sidelobes are still quite high and will overlap and interfere with primary reflections from closely-bedded formations. The third and fourth images from the top show the result of adding 2 additional octaves of lower frequencies to the first and second wavelets, respectively. These clearly show the reduction of the sidelobe

amplitudes.

Figure 2 shows a “wedge” model and the result of filtering that model with each of the wavelets shown in figure 1. The reduction in the sidelobe amplitudes by the addition of the 2 low-frequency octaves is clearly visible in the comparison between the upper 2 and lower 2 filtered panels. The improvement in the vertical resolution is also obvious when comparing the panels with the additional high-frequency octave. On these, the Rayleigh criterion of being able to identify two separate peaks as the wedge thickens is visible at 8 milliseconds reflector separation on the wavelets with upper frequency of 96 hertz versus 14 milliseconds for the wavelets with upper frequency of 48 hertz.

What is not as obvious at this display scale is the distortion of the reflector wavelets caused by the interference of the sidelobes from the nearby reflectors. Figure 3 shows zooms of the wedge model filtered by the 2 octave and 5 octave wavelets. In the 2 octave image in figure 3a, the peaks of the reflection wavelets do not align with the model spikes. At the location of the green arrow to the left the spike separation is 14 milliseconds while the peaks of the wavelets are separated by just over 18 milliseconds. At the right edge of the model, the actual model separation is 30 milliseconds whereas the apparent thickness is approximately 2 milliseconds less. In figure 3b, the broader wavelet bandwidth reduces the sidelobe interference and the signal peaks are more closely, but still not perfectly, aligned with the model spikes.

Improvement in Geophones

For many years the geophysical industry has perhaps been more focused in extending the recording bandwidth to the upper frequencies in the pursuit of higher resolution. By far the most common geophones used today have a natural frequency of 10 hertz providing a flat response proportional

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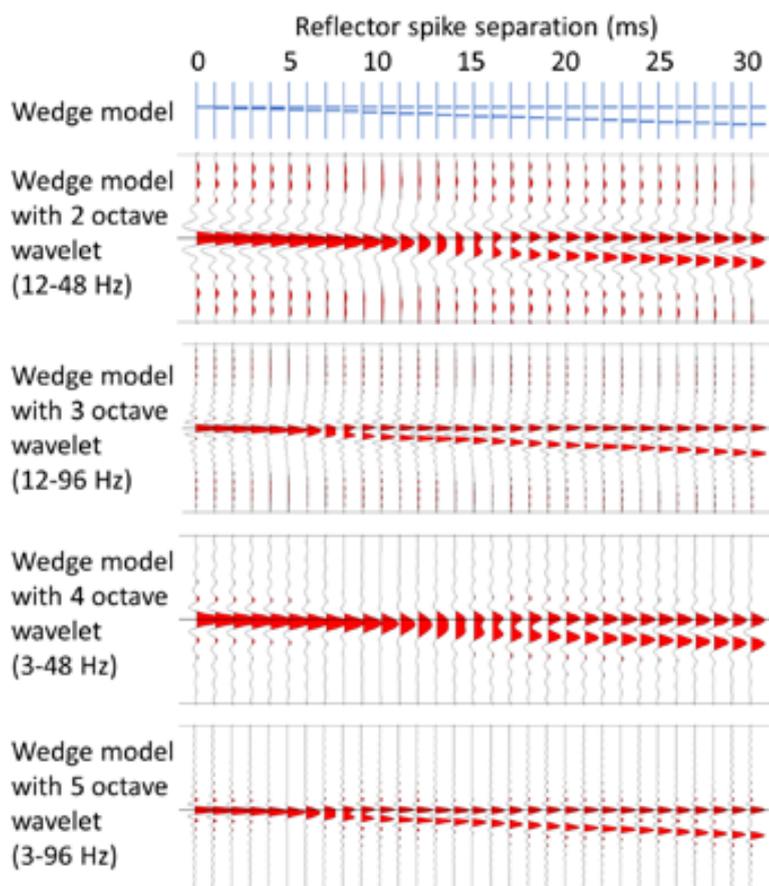


Figure 2: Wedge model (top) with wavelets applied below.

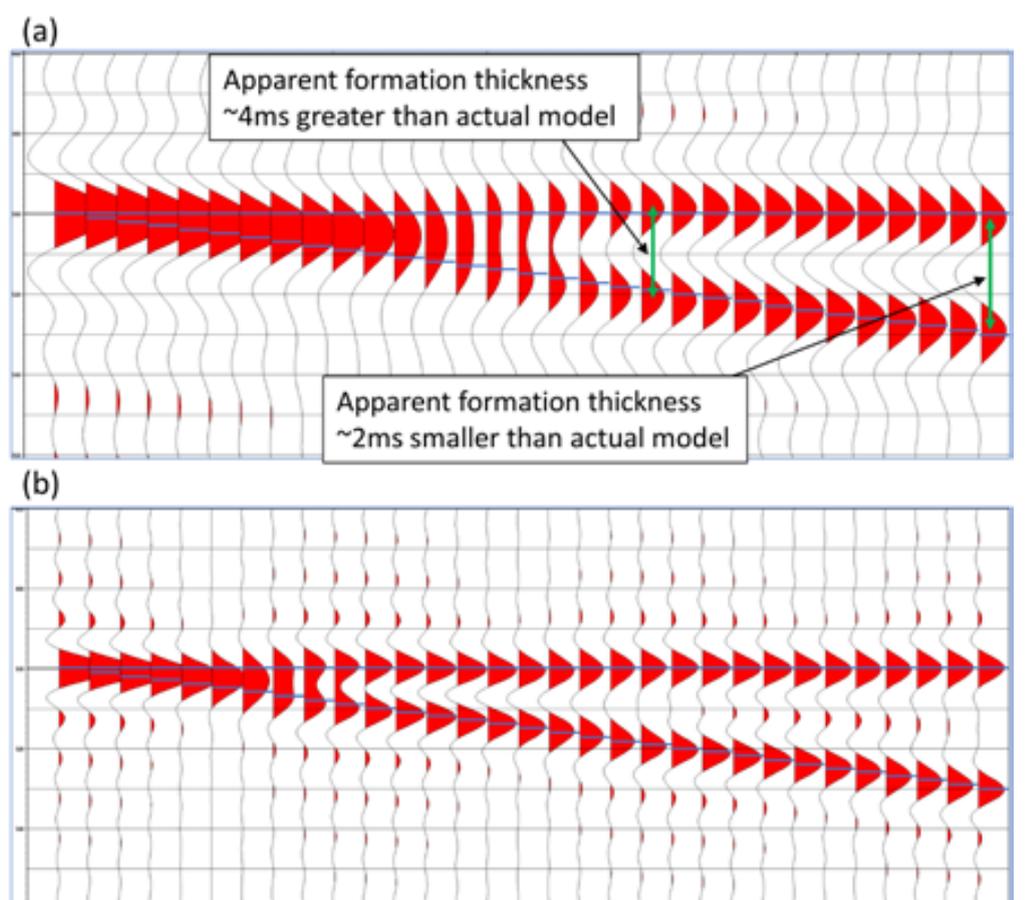


Figure 3: Wedge model zoom with (a) 12-48 hertz wavelet, and (b) 3-96 hertz wavelet, with model spikes overlaid.

◀ Continued from previous page

to ground velocity above this frequency, and a response falling at 12 decibels per octave, below. See figure 4a. Over time, improvements have been made in such geophones to tighten parameters and reduce distortion yielding the range of high specification geophones that most seismic recording crews use today. Improvements in digital filtering in our recording systems have allowed for steeper-sloped anti-alias filters pushing the -3 decibel point toward 80-percent Nyquist. As most data is now recorded at 2 milliseconds with anti-alias starting at about 200 hertz, this has led to geophones with higher spurious frequencies pushed up into the rejection band near Nyquist. All this technology improvement has gone into what manufacturers term the "industry standard": a 10-hertz geophone.

As we have seen above, extending the bandwidth to lower frequencies also improves resolution. If we wish to record signal with good signal-to-noise ratio down to 3 hertz or 2 hertz or even down to 1 hertz, we need to consider the receivers and recording systems to be used. Fortunately, this is not really an issue with modern recording systems. These systems generally have DC response. This means they can record a constant level, so have nothing "built-in" that limits their low-frequency response. Our high specification 10-hertz geophones however will show a falling response at low frequencies. A 10-hertz geophone with 70-percent damping is already -3 decibels at 10 hertz and will be an additional -24 decibels at 2.5 hertz and -36 decibels at 1.25 hertz. Although high quality low-frequency geophones are manufactured, these are generally not as common on seismic crews as 10-hertz geophones.

Another important factor to consider is that geophone signal output at the lower frequencies also suffers significant phase rotation. See figure 4b. The -12 decibels per octave roll-off and the associated phase rotation inherent in geophone design can be corrected by inverse filtering. This process flattens the geophone response below the natural frequency and applies the appropriate frequency-dependent phase rotation. It works well so long as there is adequate signal-to-(system) noise ratio. Typically, with reasonable signal strength, we can flatten the geophone response to about 2 octaves below the natural frequency, so for a 10-hertz geophone, we can get down to about 2.5 hertz. By using geophones with lower natural



Malcolm Lansley
retired in 2015 from his position as vice president of geophysics for Sercel, Inc. in Houston. He remains active in the

industry as a consulting geophysicist advising on 3-D seismic survey design for all operational areas both onshore, offshore and in the transition zone. He also continues to teach courses for the Society of Exploration Geophysicists and other companies on a variety of subjects from basic geophysics, 3-D survey design and acquisition, data processing and vibrator theory and usage. He received a bachelor of science/ARCS in physics, mathematics and geophysics from Imperial College of Science and Technology in London in 1969 and has worked continuously in the geophysical industry since graduation.

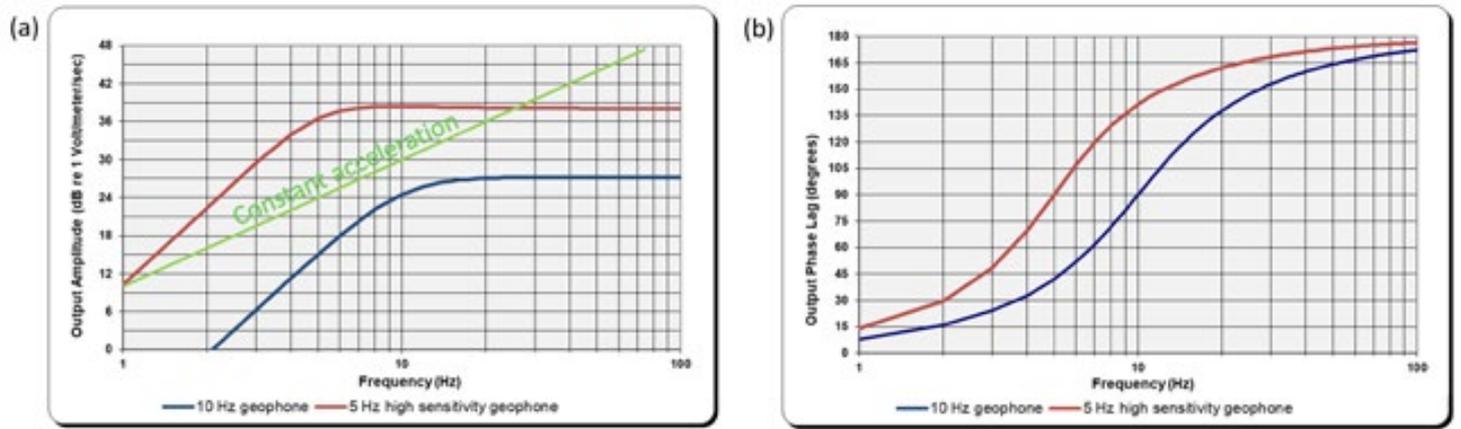


Figure 4: (a) Amplitude response of typical 10 hertz geophone and 5 hertz high sensitivity geophone. The green line shows the slope of constant acceleration (e.g. MEMS sensor) when plotted in velocity domain. (b) Phase responses of typical 10 hertz geophone and 5 hertz high sensitivity geophone.

frequencies, we can maintain sensitivity to lower frequencies and then inverse filter to very low frequencies.

Controlling for Noise

The electronics in the recording system also produce noise, thermal or Johnson noise. This noise is a function of temperature but is also frequency dependent. Typically,

electronics will exhibit an effect roughly proportional to the inverse of the frequency, or 1/f, which means that the random electronic noise will increase as frequency reduces. This effect raises the noise floor at low frequencies, so the lower frequency we record the higher the random noise contribution from the electronics themselves. This thermal or Johnson noise is random in nature and so will attenuate through

summing. The electronics can also show DC offset. This offset is frequently introduced in the A/D converter and biases the data positive or negative. The offset can be removed by computing an average value over a record and then subtracting that value from all samples. Modern systems do this as part of the acquisition process. If very long recordings are made, this offset can change over time, causing a drift effect that might look like a very low frequency, usually of period much greater than 1 second. The low frequency drift can be removed by low-cut filtering.

Another sensor type that has been available for a number of years is the MEMS sensor. MEMS (micro-electromechanical-systems) digital sensors are accelerometers and so have a lesser (-6 decibels per octave, re. particle velocity) roll-off to low frequencies (see figure 4a, green line). Additionally, they have a response to DC, which makes them good candidates for low frequency recording. However, because there is a similar 1/f, effect in MEMS sensors, the noise floor of early generations of these sensors was higher than that of geophone/analog input recording systems and therefore was a limitation for recording low amplitude low frequency signals. In conditions with extremely low ambient noise, the internal noise of the sensors could potentially become the dominant noise source. A new generation of MEMS sensors has now been released that has overcome the noise issues but, because of the large number of high performance 10-hertz geophones already in use, it might take some time before they see routine usage.

It should be noted that the self-noise of an analogue geophone is extremely low since this is caused by the thermal or Brownian motion of the air molecules surrounding the moving mass. Because the geophone low frequency roll-off is a mechanical effect, it reduces both the signal and the ambient noise to the same degree, preserving signal-to-(ambient) noise ratio. However, under some conditions, typically low signal strength, the amplitude of the signal from the geophone might fall below the noise floor or the recording system, and then the signal-to-total noise ratio becomes compromised. A significant benefit of analogue geophones in such cases with very low levels of signal is that their output may be summed in arrays to improve the signal-to-noise (both ambient and system) ratio.

Earth unrest should also be considered. In the normal seismic band, Earth tide and other low frequency motions are well below the surface ambient noise and so do not trouble us. As we go to lower frequencies these earth noises become stronger, again following a 1/f relation (Peterson model) and might need to be considered.

Figure 5 shows a test comparison of standard high-performance 10-hertz geophones in comparison with high-

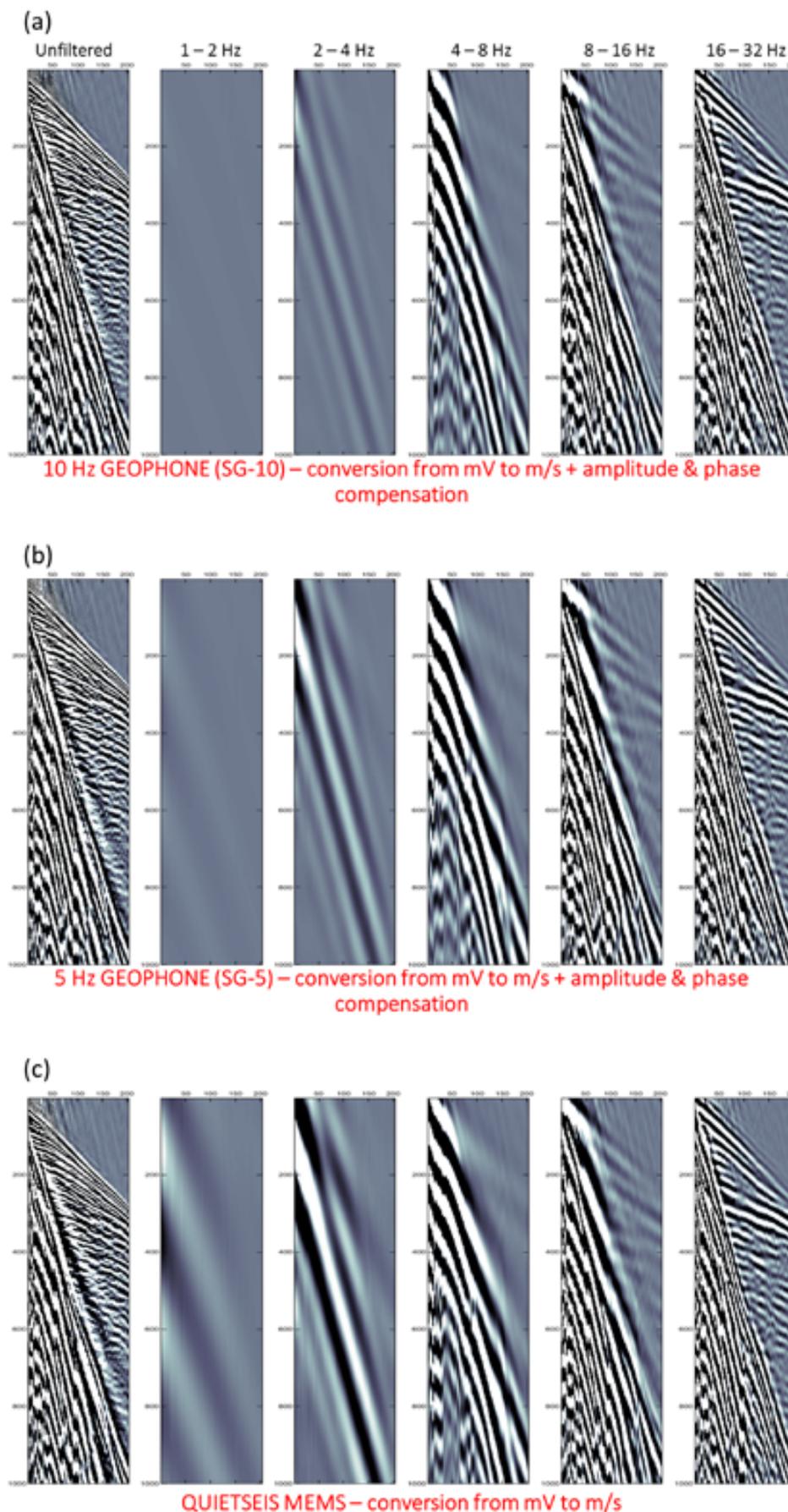


Figure 5: CRG gathers with full bandwidth (left) and frequency panels for the first five octaves (right): 10 hertz geophone (top), 5 hertz high sensitivity geophone (middle) and low noise MEMS (bottom). Geophones have inverse filters applied to correct for amplitude and phase.

See **GeoCorner** page 23 ▶

Historical Highlights



Ecuadorian plaintiffs with lawyer Steven Donziger (center) and Pablo Fajardo (right)



A group of plaintiffs brought to New York City by the Donziger team

Chevron in Ecuador

The Case of the Deceptive Underdog

In February 2011, the court in the small Ecuadorian town of Lago Agrio sentenced Chevron Corporation to pay \$9.3 billion to a group of about 30,000 Ecuadorian residents of the Amazonian region where Texaco, later acquired by Chevron, had been producing oil for 26 years.

The trial was the stuff of which Hollywood movies are made. This legal saga combined fundamental environmental issues, political intrigue, judicial corruption, corporate greed and cliff-hanging courtroom drama. Above all it unveiled the tragedy of a young and brilliant U.S. lawyer who felt he could obtain big money from a giant oil corporation while becoming a hero for the underdogs of this world.

As the events unfolded, he found out that his actions would not turn out as planned.

The leader of the legal team for the plaintiffs was a Harvard-educated lawyer named Steven Donziger, accompanied by well-known Ecuadorian environmentalists Luis Yanza and Pablo Fajardo and a group of Ecuadorian lawyers. It ran from 2003 to 2011 and was followed by related legal actions in the United States and the Netherlands; the proceedings in New York are still active.

Opening Statement

Between 1964 and 1990, the U.S. oil company Texaco operated an oil production concession from the Ecuadorian government on behalf of a consortium made up of Texaco, Gulf Oil Corp. and the Ecuadorian state oil company Petro Ecuador. In 1977, Gulf left the country and Petro Ecuador became the owner of 62.5 percent of the shares while Texaco remained as operator and minority partner. Texaco ceased operations in 1990 and, from this time onward, the sole operator in the area has been the state oil company Petro Ecuador.

On Sept. 30, 1998, the minister of petroleum of Ecuador and representatives of Petro Ecuador and other Ecuadorian government agencies related to the activity signed a full release to Texaco Oil "and all their respective agents, servants, employees, officers, directors, legal representatives, insurers, attorneys, indemnitors, guarantors, heirs, administrators, executors, beneficiaries, successors, predecessors, principals and subsidiaries forever, from any liability and claims by the Government of the Republic of Ecuador, Petro Ecuador and its

Affiliates, for items related to the obligations assumed by Texaco ..."

This was not the end of the story. In 1999, Ecuador passed a new Environmental Management Act, allowing individuals to introduce legal actions against potential transgressors of the environment. This became the legal opening used by lawyer Steven Donziger on behalf of the Ecuadorian plaintiffs, Maria Aguinda and others, to

introduce a 2003 legal action in Lago Agrio against Chevron, the new owner of Texaco assets and liabilities. The nature and length of this trial, which was based on the retroactive application of the new law, captured much attention in international oil and environmental circles. As a petroleum geologist familiar with the area, I became very interested in the proceedings and started to read all I could about it.

Trial and Verdict

Stunningly, the majority partner in the consortium, the state oil company Petro Ecuador, was not named as co-defendant in the action. The only defendant was Texaco, now Chevron, the foreign company which had left the country years before, although the sole operator in the area since 1992 had been the Ecuadorian state oil company. It seemed to me that a "crime scene" that had been trampled by other actors could not be easily connected to someone who was long absent.

In 2009, I met separately with representatives of the two sides: Karen Hinton, a Washington, D.C. spokesperson for the plaintiffs and Jim Craig, a spokesperson for ChevronTexaco. I told Hinton that in my view, Petro Ecuador was the party primarily responsible for any damages to the environment in the area. She told me they had retained a very competent technical firm, STRATUS, from Denver, Colo., which had been studying the case. Craig let me know his doubts about the transparency of the trial. He later sent me information about an expert named by the court, Stalin Cabrera, whose training and experience in petroleum matters left much to be desired. This expert had submitted a report in March 2007 that described the damages presumably done by Texaco, asking for total remediation and compensation costs close to \$8 billion, later doubled to \$16.3 billion for "unjust enrichment" on the part of Texaco. In November 2008, the expert updated his report increasing his assessment of damages to \$26 billion, in order to compensate for more pollution-related deaths than previously reported.

In February 2011, the Lago Agrio court decided against Chevron, ordering the company to pay around \$19 billion, the exact amount fluctuating after several appeals by the company, finally reduced to \$9.3 billion.

Chevron Investigations Cast Doubt on the Verdict

In parallel with the trial, Chevron had been investigating the activities of the main actors and progressively discovered very damaging information against the judges, the court experts and the legal team of the plaintiffs. Some of the findings included the following.

In September 2009, Chevron found video information on a \$3 million bribe scheme



Map of the area from "Law of the Jungle," by Paul M. Barrett

Continued on next page ▶

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involving the case's judge and Ecuadorian government officials, including the legal adviser to Ecuadorian President Rafael Correa, an action designed to influence the outcome of the trial in the plaintiff's favor. Transaction records found in Texas banks further documented the bribe scheme.

It was also found that Cabrera's report had not been written by him but by the Colorado firm STRATUS and paid for by the plaintiffs. A book on this case, "Law of the Jungle", by Paul M. Barrett, details (pages 151-157) how STRATUS was paid \$1.7 million to generate a 3,000-page report signed by Cabrera, recommending that Chevron pay \$16 billion for damages. For his services, Barrett reported, the Donziger team paid Cabrera at least \$392,000.

A documentary film titled "Crude," produced by Joseph Berlinger, highly supportive of the plaintiffs, generated much more material than utilized in the final product. In their New York Tribunal action against the Ecuador verdict, Chevron demanded and successfully obtained the total footage, which revealed meetings of the plaintiffs planning the fraud against Chevron. A video posted at the Chevron-run The Amazon Post website contains abundant graphic material left out of the final version of the documentary showing Donziger describing the Ecuadorean court system as corrupt and joking about assassinating an Ecuadorean judge – or at least making him fear he will be assassinated. In the videos, the plaintiffs discuss the lack of evidence on their side while Donziger points out that "they can simply create their own facts." During a meeting attended by the court expert Cabrera, Donziger and the consultants retained by the plaintiffs, they also discuss how they will write the court expert's report. In this video, Donziger is seen and heard stating that the work plan would involve "writing the expert's opinion." The meetings can be seen at AmazonPost.com.

A July 2013 report by the New York Times describes how one of the STRATUS consultants tells Donziger that there was no evidence of pollution in the oil pits examined, and how Donziger responded, "This is Ecuador, OK. At the end of the day, there are a thousand people around the courthouse and you will get whatever you want."

On the basis of these findings, most scientific experts originally contracted by Donziger ended up testifying against him at the New York trial, as reported by The Amazon Post.

In January 2013, Chevron presented evidence that the Lago Agrio judge, Nicolas Zambrano, had not been the author of the judgment. The document had apparently been ghost-written by a former judge, Alberto Guerra, a job for which, Chevron claimed, he had been paid by the plaintiffs. In his book (p. 234), Barrett reports that linguistic experts hired by Chevron demonstrated that about one-third of the judgment had been lifted verbatim from internal memoranda written by the plaintiff's team.

In 2007, Ecuadorian President Rafael Correa mounted a political campaign designed to intimidate the judge in charge of the case and browbeat the defendants. Among other things he declared: "Chevron-Texaco's attorneys, they (are) lawyers 'vende patria' (sold to foreign interests), who for a fistful of dollars are capable of selling their souls, their country. We also have people from Petro Ecuador who in 1998 signed an Agreement declaring everything had been remediated, when many of these pits had not been even covered. I hereby call the Attorney General to present a report to the General Comptroller's Office establishing criminal responsibilities against Petro Ecuador's officials who signed this nonsense."

However, the attorney general never found a basis to write such a report.

In order to pressure Chevron to pay the amount dictated by the Ecuadorian verdict, Correa mounted a campaign called "Dirty Hands in Ecuador." He visited the area and



Ecuadorian President Correa dipping his hand in the wrong pool



Actor Danny Glover became one of President Correa's recruits for his campaign.

placed his hands in an oil pool, claiming this was the proof of Chevron's crime. However, the site where he placed his hand in September 2013 was not one of Texaco's old oil pits but Petro Ecuador's.

The campaign recruited Hollywood actors such as Danny Glover, Mia Farrow and Darryl Hannah and other celebrities, some of whom were reported to have received substantial payments to support the campaign.

Courts Absolve Chevron, Condemn Donziger

In February 2011, Chevron filed suit against Donziger in a Manhattan court, based on the Racketeer Influenced and Corrupt Organizations Act (RICO), Judge Lewis Kaplan presiding. Pablo Fajardo, Luis Yanza and the consulting firm STRATUS were named as co-defendants and organizations that had supported Donziger such as Patton Boggs and Kohn Swift, Amazon Watch and Burford Capital were named as co-conspirators. This trial ended in March 2014



Gustavo Coronel received degrees in petroleum geology from the University of Tulsa and the Universidad Central de Venezuela. He was a Harvard fellow of international affairs and earned a master's in international public policy from Johns Hopkins University. Coronel worked for 30 years in the international petroleum industry in Venezuela, the United States, Holland, Indonesia, Bolivia, Peru, Ecuador, Argentina, Surinam, Nigeria and Algeria. He is a founding member of the Board of Petróleos de Venezuela. He has worked on petroleum projects for the InterAmerican Development Bank, was a representative of Transparency International in Venezuela, was founder and president of the NGO "Pro Calidad de Vida," and gave the workshop "Strategies to Control Corruption" in Venezuela, Panama, Bolivia, Paraguay and Mexico to about 13,000 people. He has written five books on Venezuelan politics and petroleum and is an active blogger at LasArmasDeCoronel.blogspot.com, where a detailed list of references may be found.

the government of Ecuador to pay the legal costs incurred by Chevron.

An Ideological Twist

The story is still unfolding. Donziger has been convicted but his cause has been taken up by several environmental groups, who see him as a hero battling the all-powerful oil company. The case against Chevron has almost become a religious movement, taken up by some groups that consider Chevron the guilty party. Recently, a group of 30 Nobel Prize winners published a manifesto, which can be found at CourtHouseNews.com, entitled, "30 Nobel Laureates Demand That Chevron Face Justice for Amazon Pollution," in which they hail Donziger as a champion of the poor and the weak and, as the title conveys, demand that Chevron pay for the damages done in Ecuador.

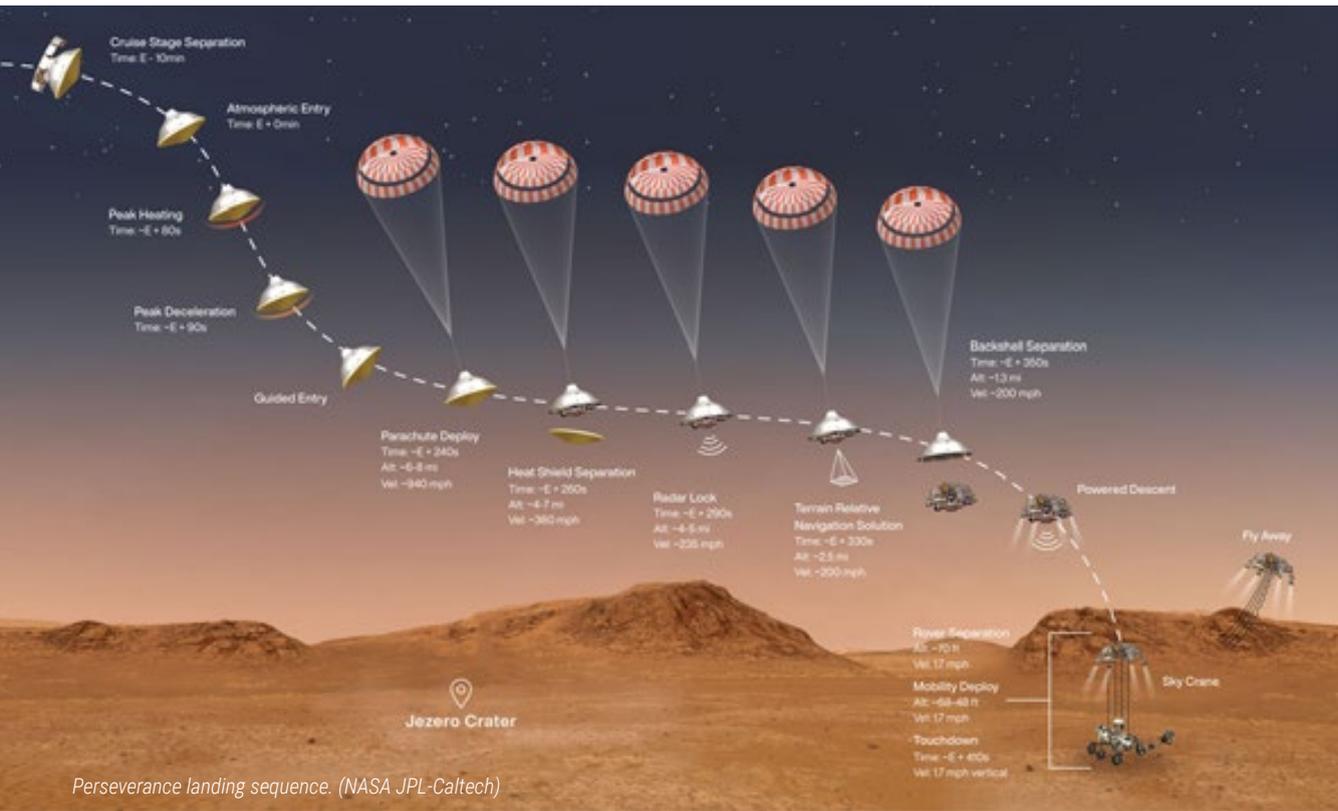
Although it seems tempting to side with such a distinguished group, the evidence against Donziger and his team is overwhelming. It is perilous to politicize the environmentalist cause as these groups are trying to do. By calling upon environmentalists to defend Donziger and to indict Chevron, these ideologically driven groups exert a subtle form of extortion on all who support the cause of the environment. Many of us defend the environment and favor the development of greener, renewable sources of energy but, knowing the facts of the Chevron-Ecuador case, find it impossible to side with Donziger and against Chevron.

The preservation of our environment is one of the noblest human aspirations. All life should be respected, the preservation of the species is more important than any one individual, and the fate of the planet transcends national boundaries and political ideologies. Environmentalism should never become tainted with partisan politics or ideological astigmatism. 

Editor's Note: The author notes that he does not have, and never has had, any relationship with any of the parties mentioned in this article, nor has he ever received any compensation from any source for expressing his views on this case.

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

Mars 2020 Perseverance Rover and International Mars Fleet Arrival



Mars Perseverance Watch Party

The NASA Perseverance mission will land on Mars on Thursday, Feb. 18 at approximately 12:30 p.m. Pacific time (2:30 Central). Join AAPG President Rick Fritz and members of the AAPG Astrogeology Committee and others for a watch party and discussion. Visit AAPG.org for the exact time and link.



As this EXPLORER issue goes to press, there are three international robotic missions headed to their encounters with Mars this February. We wish all three missions success!

The United Arab Emirates' Hope Mission will enter Mars orbit on Feb. 9, 2021. Its goal is to study Martian atmospheric dynamics and weather.

China's Tianwen-1 Mission is expected to enter Mars orbit on Feb. 10, 2021. A lander with a Mars rover will

be deployed in May 2021 for a proposed landing zone in Utopia Planitia. The mission goals are to find evidence for current and past life, characterize Martian soil composition, and map water ice distribution.

The NASA/Jet Propulsion Laboratory Mars Perseverance rover is scheduled to land at Jezero Crater on Mars on Feb. 18, 2021. At the time of writing,

Continued on next page ▶

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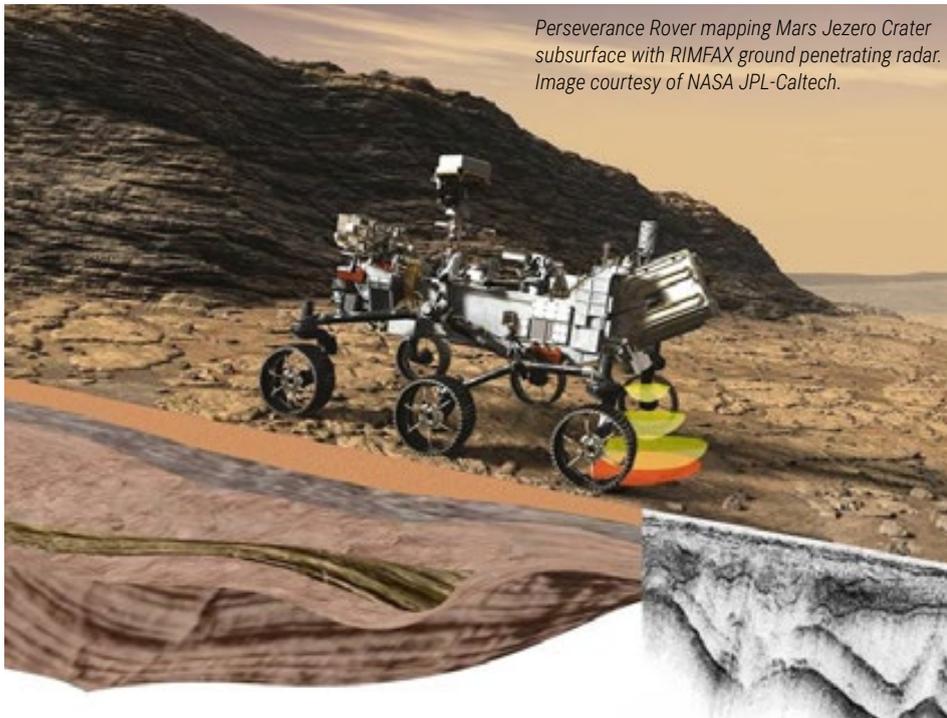
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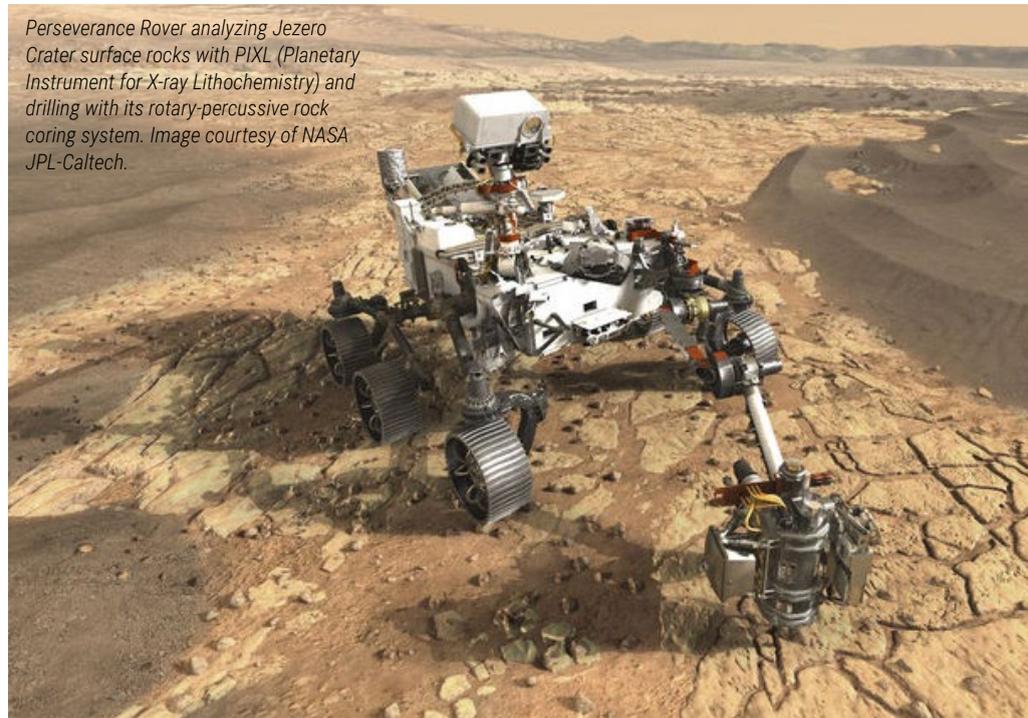
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Perseverance Rover mapping Mars Jezero Crater subsurface with RIMFAX ground penetrating radar. Image courtesy of NASA JPL-Caltech.



Perseverance Rover analyzing Jezero Crater surface rocks with PIXL (Planetary Instrument for X-ray Lithochemistry) and drilling with its rotary-percussive rock coring system. Image courtesy of NASA JPL-Caltech.

◀ Continued from previous page

Perseverance is 34 million miles from the Red Planet with 88 percent of its journey complete. The Perseverance rover is a fully packed geology science laboratory. The car-sized rover is about 10 feet long, 9 feet wide, 7 feet tall, and weighs 2,260 pounds on Earth. The October 2020 EXPLORER reviewed Perseverance rover's geology instrumentation. The November 2020 EXPLORER featured an article on Jezero Crater geology.

Seven Minutes of Terror

Only 40 percent of the missions ever sent to Mars have been successful. Perseverance is the fifth rover to attempt landing on Mars. The rover's complex landing system was successfully pioneered by the Curiosity rover, which landed at Gale Crater on Aug. 6, 2012. The landing sequence is dubbed "seven minutes of terror." The landing sequence begins by entering Mars atmosphere on a heat shield

like a flaming meteor at 20,000 miles per hour. The heat shield is jettisoned at 1,500 mph and a special parachute is deployed to further slow the rover toward its designated landing site.

The landing system will use Terrain Relative Landing for the first time to program adjustments for a more precise landing. The system employs a camera and computer to quickly identify mapped features on the surface and to determine exactly where it's heading relative to program. The landing computer will select the safest spot in the designated landing zone.

At an altitude of 13 miles and velocity of 200 mph, the rover jettisons the parachute and backshell. It then transitions into powered flight with eight thrusters on its sky crane.

At a final descent speed of about 2 miles per hour, 12 seconds before touchdown, and 66 feet above the surface, the sky crane lowers the rover on a set of cables. As soon as the car-sized rover senses that its wheels have touched the ground, the cables are severed and the sky crane flies away.

A Geologist in the Field on Mars: Core, Baby, Core!

The Perseverance rover has a primary mission span of at least one Martian year (687 Earth days). Hopefully, an extended mission will carry on science for many more years. After instrumentation check out, Perseverance will begin its search for past life in Jezero Crater, test the Ingenuity drone helicopter, and cache samples for future return to Earth.

Perseverance has a drill for coring on its robotic instrument arm. The drill is larger and more capable than the one on Curiosity rover. The upgraded instrument is a rotary percussive drill that can cut intact rock cores. The cores will be placed in sample tubes via a complex storage system. The saucer shaped bit carousel on the front of the rover holds drill bits and provides them to the corer on the turret arm. The bit carousel transfers sample tubes cores into the belly of the rover. Sample return to isolated, sterile labs on Earth will require a separate mission, perhaps as early as 2031.

Good luck and Godspeed on your landing Perseverance! Then get to work! 



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"I get in-depth information on prospects, see the science that's behind them, and connect with the people bringing the opportunities forward."

D. Cox, Storm Energy

Foundation Update

Student-Led Water Development in the Andean Puna

“Bonanza en los Andes” was a two-year Geoscientists Without Borders-funded project focused on the Andean community of Zurite, Perú.

Bonanza was designed around three interconnected themes:

- ▶ A community-based irrigation canal development project
- ▶ A hydrogeologic investigation of water resources in the understudied Andean puna
- ▶ An educational program designed to train students in multidisciplinary research to bridge gaps between science and society

Zurite has a population of 4,000 and is located at 3,400 meters above sea level on the edge of the Anta Plain, approximately 30 kilometers northwest of Cusco. More than 70 percent of Zuriteños devote themselves entirely to agriculture and there is a rich history of agriculture and animal husbandry. Major crops include corn, wheat, quinoa and forage for livestock. Rainfall is strongly seasonal, with only 10 percent of the 855 millimeters of mean annual precipitation falling between May and September. Zurite derives irrigation and municipal water from the 6.14-square kilometer Ramuschaka Watershed, which drains grasslands rising dramatically to 4,500 meters above sea level. The Upper Ramuschaka Watershed (URW) is part of the puna biome, a seasonally dry grassland above the tree line and below the permanent snow line along the spine of the central and southern Andes. Many headwater streams originate in the puna and although these streams provide water to Andean communities large and small and are likely to become more important



Zurite community partner Tomás Ruiz López swings the combo (sledgehammer) to produce a seismic source along a seismic refraction survey crossing a bofedal in the Upper Ramuschaka Watershed. Yojana Miraya Oscco (M.S., HSU Environment and Community 2018) and Jazmin Sandoval (Film, 2019) provide support carrying equipment. Yojana assisted in translating between Spanish, English and Quechua and both Yojana and Jazmin conducted interviews with community members, students, staff, and PIs.

as glaciers recede, their hydrology is poorly understood.

Community Impact

We collaborated with the community to build 1.3 kilometers of irrigation canals. Principal investigators developed formal agreements with three community groups, including the municipality of Zurite. Our project contributed \$20,000 to the \$70,000 canal project. We also collaborated with engineers on the hydraulic design. More

The AAPG Foundation since 2015 has supported the humanitarian initiative “Geoscientists Without Borders,” which provides relief and geoscience expertise to help communities overcome the threats of resource shortages and environmental hardships, both natural and human induced.

The international program, administered by the Society of Exploration Geophysicists, started in 2008 with a grant from founding supporter Schlumberger to “support

than 100 families directly benefit from irrigation water now reaching their fields by way of the new canals. Principal investigator Oshun gave community presentations on the objectives of the Bonanza project and presented the municipality with a progress report in 2020. The report presents initial results on water resources in the Ramuschaka and a brief assessment of landslide hazards. The hydrologic results will help guide sustainable water management.

The community issued a statement that read in part, “We are infinitely grateful for

humanitarian application of geoscience knowledge and technology around the world.”

Water shortages, landslides, earthquakes and tsunamis are all among the conditions tackled by the geoscience teams who help communities under the GWB banner.

“The AAPG Foundation is excited to support Geoscientists Without Borders,” said AAPG Foundation Chair Jim Gibbs. “Supporting geologic initiatives that also help

your support ... that perhaps we will never be able to return to you, but for which you should feel a great sense of satisfaction.”

Hydrogeologic Impact

Our hydrogeologic study has produced several key results, many of which are in preparation for publication. First, we identified and mapped the geology of the URW to reveal Eocene sedimentary units include limestone, sandstone and mudstone. An Oligocene quartz monzodiorite intrusion outcrops in the west. Seasonally saturated

Continued on next page ▶

provide communities with healthier places to live is of real value to us.

“Obviously, the global aim and application of the humanitarian aspects of geoscience are efforts we can truly be proud to support,” he added.

AAPG Editor Robert Merrill, of Cathart Energy in Houston, has been an active supporter and participant in GWB initiatives, and he encouraged and coordinated this month’s report.

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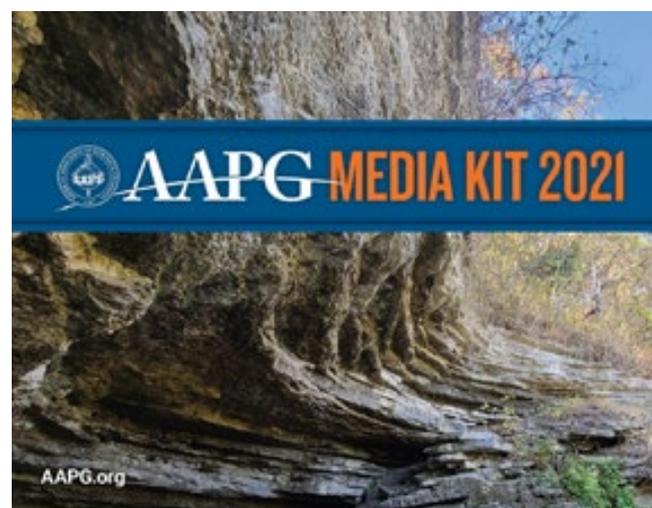
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Jasper Oshun is an assistant professor of geology at Humboldt State University in Arcata, Calif. He is a process geomorphologist and critical zone expert. His courses and research focus on geomorphology, hydrogeology, fluvial geomorphology and stream restoration and water resources. He founded and developed Global Student Embassy, a grassroots international relations NGO connecting high school and college students with their international peers in project-based exchanges throughout Latin America.

Margaret Lang is a professor of environmental resources engineering at HSU. She teaches fluid mechanics, design

of hydraulic systems and surface and groundwater hydrology and conducts research on ecologically appropriate and resilient infrastructure design. She is also on the advisory board for HSU's Department of Education HSI-STEM grant.

Kristina Keating is an associate professor of geophysics, Earth and environmental Sciences at Rutgers University-Newark. She is a near surface geophysicist and runs the Geopaths program at RUN. She teaches courses in environmental geology, applied geophysics, quantitative methods in the geosciences and geophysical inverse methods.

◀ Continued from previous page

peat forming wetlands, known as bofedales, are found in low gradient basins across the upper watershed. Our hydrologic analyses reveal that 60-70 percent of precipitation leaves the watershed as runoff, and the remaining moisture evaporates off seasonally saturated bofedales, or is transpired by puna grasses. Geophysical data show a deeply fractured and weathered interior of upper hillslopes that thins substantially beneath the interior basins of the bofedales. Precipitation falling on the uplands travels via subsurface pathways and collects in the high porosity peat of the bofedales, which act as a sponge and saturate during the wet season. During the dry season, water drains slowly from bofedales through the underlying low-conductivity clay layer. Currently, we are quantifying water storage within and water yield from bofedales, which cover about 12 percent of the watershed but appear to contribute substantial quantities of water to dry season flow.

Student Impact

Over a two-year period, 29 undergraduate and graduate students from seven

different disciplines, including geology, geophysics, engineering and environment and community participated in Bonanza. Students enrolled in a year-long program centered on four weeks of field research in Zurite and the URW. In the spring semesters, we taught a preparatory class that cultivated communication across disciplines, introduced students to independent research, guided students in literature reviews and hypothesis development and explored existing data sets. In-class activities were designed to improve essential skills such as science communication, team building, and the Spanish language. By the end of the course, students were mentally and emotionally prepared to travel to and spend a month living in Perú and empowered to take the lead on specific research tasks.

We conducted four-week field campaigns in 2018 and in 2019. In 2018, nine students from Humboldt State University and one student from Lima joined PIs to map geology, conduct seismic refraction surveys and install hydrologic monitoring equipment in the URW, and survey the existing and proposed canals in Zurite. In 2019, principal investigators guided 13 students from U.S. universities and five students from Cusco.

See Foundation page 23 ▶

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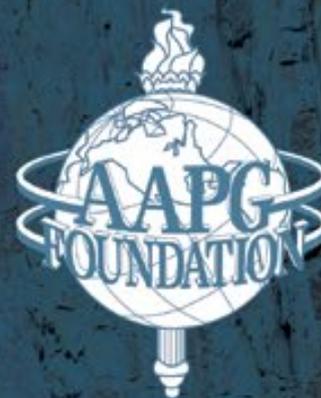
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DEANA AND PAUL STRUNK MILITARY VETERANS SCHOLARSHIP PROGRAM

OPENS: Feb. 15, 2021 | DEADLINE: May 15, 2021

The Military Veterans Scholarship Program (MVSP) provides grants to veterans pursuing geoscience degrees at a four-year college or university in an effort to aid in their transition from military service to civilian career opportunities. Eligibility also includes military dependents (spouses and children) for the following categories: deceased, disabled, active and veteran. Grants range from \$2,500 to \$5,000.

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Heat from page 12

deep sedimentary basins, using data from existing oil and gas wells. "You can find conditions that are above 350 degrees. These have not been exploited to date by energy companies for geothermal energy," he said. "That's what got me into this field."

A key factor in assessing the state of the geothermal industry was to understand its successes and failures. Cutright started mapping bottomhole temperatures and studying roughly 300 active geothermal sites around the world. For every site operating below 10 percent of its intended design capacity, he looked for the reasons why. Geothermal projects cannot afford dry or underperforming wells, and failures to understand the site geology and deep flow systems often contribute to poorly performing projects, he said.

At one time, Chevron was the largest producer of geothermal energy in the world, having successfully designed wells and operated more than 350 megawatts of geothermal generation in the Philippines and Indonesia. The major sold the wells approximately four years ago for nearly \$4 billion.

"It's a great investment if you know how to put a program together and if the per-well cost is managed well," Cutright said.

Hoping for a Parachute

Over the years, Cutright has been building a global map of subsurface geothermal resources largely based on data from the oil and gas industry. Today, it is supported by a staggering 6 to 8 terabytes of data and is used to identify new and undeveloped geothermal resources.

Pfeffer focuses on developing strategic

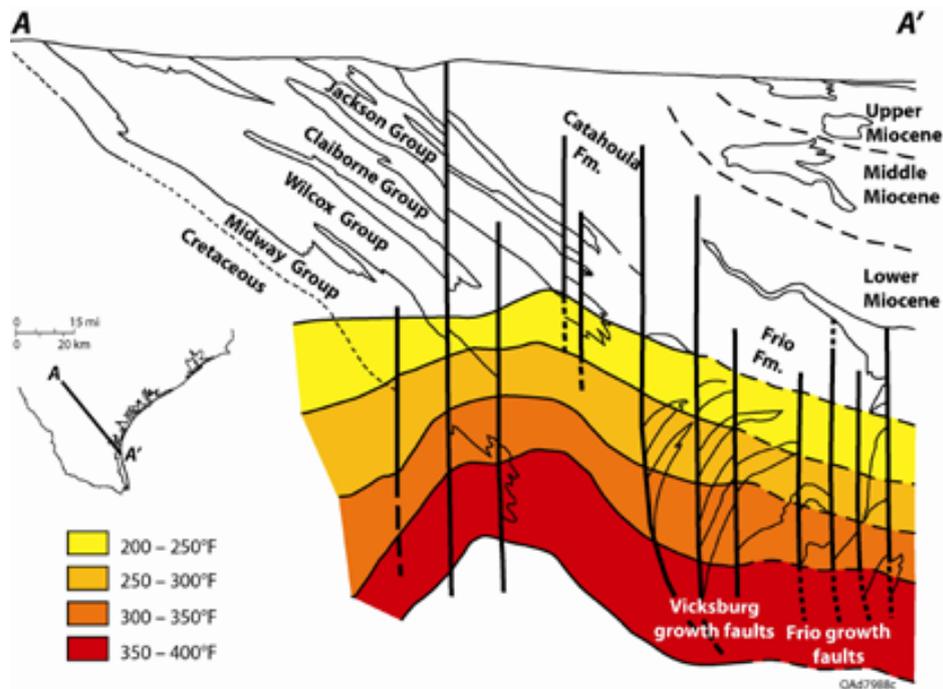


Figure by UT Bureau of Economic Geology (B. Cutright) illustrating formation temperatures in Texas Gulf Coast deep sedimentary formations

business plans and attracting investors, showing how the resource is both clean, affordable and highly competitive with wind and solar energy.

"People have the ability to understand that the wind blows and the sun shines. We have to go the extra step and prove that this resource, which you cannot see, really exists," Pfeffer said. Their extensive dataset of geothermal resources has completely eliminated the need to prospect, significantly reducing risk and cost.

Highly intrigued by their data and approach, Schlumberger proposed a partnership that created GeoFrame Energy in September 2020.

"We were very interested in the way they positioned geothermal energy and their skillset," said Ashok Belani, executive vice

president of Schlumberger New Energy. "They could show that this would be successful."

Belani said that Schlumberger's expertise in drilling technology, subsurface characterization and construction dovetailed nicely into Cutright's and Pfeffer's business model.

Interested in creating a company that could provide geothermal energy on a global basis, Belani said, "Theirs was the right company at the right time to work with something that could be big. This is something that can greatly benefit the world."

Cutright added, "We are on the cutting edge of learning how to transfer our petroleum expertise to produce renewable energy. I believe in this so strongly that I risked everything I had to do it. It's like

jumping out of an airplane and hoping you have a parachute."

Benefits of Geothermal

By removing the need for prospecting, Nevis was able to choose geothermal over other forms of renewable energy. Compared to solar and wind, which require large footprints to operate, geothermal wells require very small land area. In fact, geothermal plants are less than one-tenth the area of solar or wind facilities, Cutright said.

Geothermal energy also is continuously available, as it relies on the continuous flow of heat from the subsurface rather than unpredictable sources tied to weather. Because the actual energy source is underground, islands that are subject to extreme weather events are ideal candidates for geothermal power. In Nevis, GeoFrame redesigned powerplants to withstand up to Category 5 hurricane winds.

"Up front, geothermal looks more expensive than solar and wind. It does take a greater capital investment," Cutright said. "But the fuel is free. We are basically pre-purchasing the fuel to drive the plants in the future, so it's actually cheaper."

Because the fuel is pre-paid, it is possible to predict with certainty what future energy costs will be.

"In one fell swoop we are eliminating diesel, and it will be a dramatic reduction in the cost of power," Pfeffer said. "We have a passion for what we are doing. We can see a nice return but we are actually doing something really good for people and the environment."

"Petroleum will always be important. We're not leaving it behind," Cutright added. "But we need to think as energy professionals. This is within the areas of expertise of our members and has the capacity of changing the world."



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More information on Oklahoma State University and the Boone Pickens School of Geology is on the web at <http://go.okstate.edu> and <http://geology.okstate.edu>, respectively. Oklahoma State University, as an equal opportunity employer, complies with all applicable federal and state laws regarding non-discrimination and affirmative action. Oklahoma State University is committed to a policy of equal opportunity for all individuals and does not discriminate based on race, religion, age, sex, color, national origin, marital status, sexual orientation, gender identity/expression, disability, or veteran status with regard to employment, educational programs and activities, and/or admissions. For more information, visit <https://eeo.okstate.edu>.

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GeoCorner from page 15

sensitivity 5-hertz geophones and the latest generation of MEMS accelerometers. The geophones have all been inverse-filtered to remove the low frequency roll-off and the corresponding phase effects. The MEMS accelerometers have been integrated to velocity. Thus, all displays are of ground velocity. In this comparison, it is clear that the MEMS sensor has the strongest low frequency signal, the 5-hertz high-sensitivity geophone is next, and the 10-hertz geophone is last.

Conclusions

Given today's seismic technologies and the current availability of equipment, there does not appear to be a universal solution to the challenges of low-frequency recording. There are many variables to consider in choosing the most appropriate equipment. In many areas, we will probably see continued use of 10-hertz geophones because of their availability. In addition, if the signal levels are low, they can be used in arrays to improve the signal to the ambient, and recording system, noise ratio. We might continue to see use of 5-hertz geophones in areas where they are already being deployed, but the future seems to be with using low-noise MEMS because of the improved signal-to-noise over a wider bandwidth than with conventional moving-coil geophones.

Acknowledgements

The author would like to thank Sercel for permission to use the data set in figure 5. 

(Editors Note: The Geophysical Corner is a regular column in the EXPLORER, edited by Satinder Chopra, Founder and President of SamiGeo, Calgary, Canada, and a past AAPG-SEG Joint Distinguished Lecturer.)

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Foundation from page 21

Students expanded geologic maps, took discharge measurements throughout the watershed, flew a drone to collect aerial imagery to generate a digital elevation model, installed deep and shallow monitoring wells, conducted electrical resistivity surveys, seismic refraction surveys and nuclear magnetic resonance surveys, collected geospatial data using a real-time kinematic GPS and completed surveys of the existing and proposed canal network while collaborating with local engineers on the hydraulic analyses and canal design. Although students specialized in certain research areas, they also rotated

through different tasks to gain experience using different equipment and taking measurements. For each field campaign we stayed with host families in Zurite, and students served as informal ambassadors to the community.

In the fall semesters following our two summer field campaigns, students enrolled in a research course. Principal investigators guided students through data analysis, interpretation, figure development, abstract writing and paper writing. Students produced written reports and gave presentations to the class on topics such as: creating a DEM from drone derived imagery, an analysis of current and projected irrigation needs and a water budget of the URW. One student presented a poster on initial results of the seismic refraction surveys at the Fall American Geophysical

Union Conference in Washington, D.C. In December 2019, two students presented interpretations of geophysical data and one student presented the results of hydrologic measurements at the Fall AGU Conference in San Francisco, Calif.

The experience cultivated patience, understanding, motivation to improve our planet and, ultimately, peace.

Students left our program with new perspectives: "This trip made me rethink what approach I want to take to grad school (location, concentration), and made me think more about pursuing a career in water resources," said one student.

Our project proves international research can be designed and conducted in a way that produces benefits to U.S.-based and local students, principal investigators and the local community. 

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- Theme 3:** Geological Characterization and Evaluation Spanning the E&P Lifecycle
- Theme 4:** Geophysical Unconventional Reservoir Analysis
- Theme 5:** Geomechanics – The Intersection of Geoscience and Engineering
- Theme 6:** Applied Geochemistry for Unconventionals: From Source Rock to Produced Hydrocarbons
- Theme 7:** Machine Learning, AI, and Big Data in the Digital Oilfield
- Theme 8:** Unlocking the Production and Recovery Potential of Unconventionals
- Theme 9:** Reserves Estimation and Production Forecasting
- Theme 10:** New Materials, Innovative Technologies as Applied to Unconventionals
- Theme 11:** International and Emerging Challenges of Unconventional Resources: Integrated Geoscience and Engineering
- Theme 12:** Business of Unconventional Plays
- Theme 13:** Sustainability, Rapid Industry Change, and the Social License to Operate
- Theme 14:** Special Sessions

AAPG Women's Network Launches Mentoring Program

Mentoring, as defined in Oxford Dictionary, is "the practice of helping and advising a less experienced person over a period of time, especially as part of a formal program in a company, university, etc."

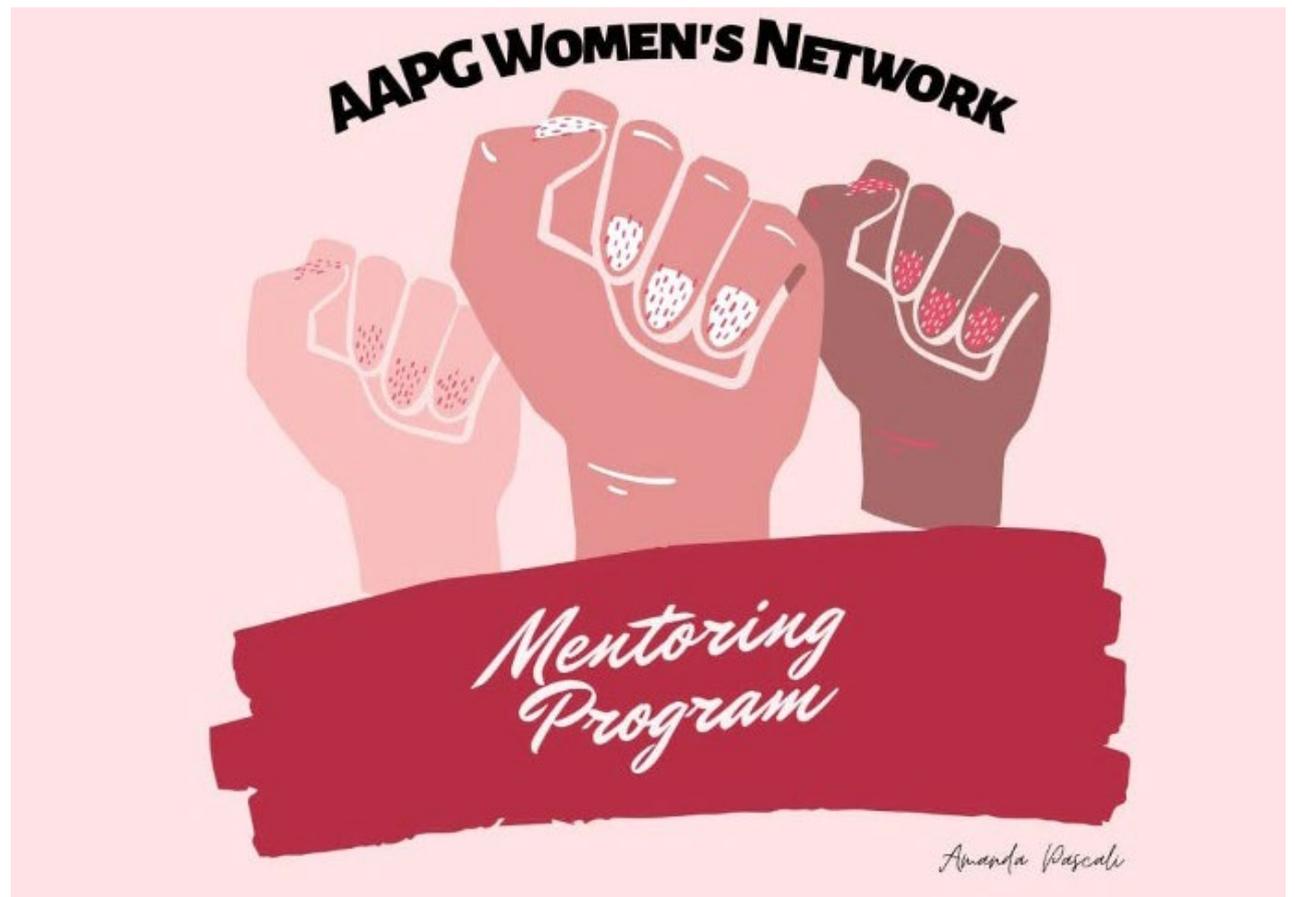
As we face difficult times with new challenges in the energy industry, we must strive to enhance both soft skills and technical skills, while continuing to strengthen our community. Mentoring programs provide mutually beneficial, win-win relationships to accomplish these goals, demonstrated by outstanding results for both mentors and mentees in organizations and companies that have implemented them.

To support our members, the AAPG Women's Network is launching the AAPGWN Mentoring Program – a tool for promoting women and supporting their career development within the energy industry and related fields.

The goal of the program is to build a cohesive community of geoscientists in the energy industry, improve career development resources for women and minorities, and increase knowledge sharing among our global members. This program has been carefully planned over the last year to add significant value to our community.

A diverse group of mentors (gender, ethnicity, race, age) are invited to contribute to this program by helping develop mentees through active listening, sharing industry knowledge, and "lessons learned" through failures and achievements, while providing feedback and advice to mentees. Mentors may benefit by being exposed to online and social media trends and gain awareness about ever-evolving diversity and inclusion ideologies, trends and topics. We view this as a way to embrace the millennial and upcoming GenZ population in the workforce and make sustainable, cross-generational relationships and viewpoints. Our goal is for mentors to remain relevant to the younger generations to influence and positively impact the future.

Women and individuals who identify as being a woman who apply to become AAPG member mentees should be interested in expanding their capabilities, willing to ask for help and accept feedback, and be proactive and responsible. Women who are first-generation college graduates and energy geoscientists may find this program of high value in order to receive mentoring from compassionate senior geoscientists. With a growing number of geoscientists from "non-traditional"



backgrounds of greater diversity, mentoring programs like this will be key in retaining women and minorities long term and helping early career geoscientists navigate their careers through the energy transition.

Interested applicants will complete forms with matching criteria (for example, "What topics are you most interested in being mentored in?"), and mentor-mentee matches will begin a formal mentoring cycle in January 2021. After a virtual kick-off event early January, pairs are encouraged to meet virtually six times between January and April 2021.

This program is sponsored by AAPG and is intended to take place on an annual basis. You do not have to be an AAPG member to mentor, however, mentees are required to join AAPG (Chevron membership scholarship is available). AAPGWN is looking for sponsorships for 2021-2022 fiscal year to continue its Mentoring Program after April, 2021. Please email us at aapgwn@gmail.com for more sponsorship information. Special thank you AAPGWN Publicity Director, Amanda Pascale for creating the artwork for this article.



NEW DATES

9-11 November 2021 | Yangon, Myanmar

SUPPORTED BY MYANMAR GEOSCIENCES SOCIETY

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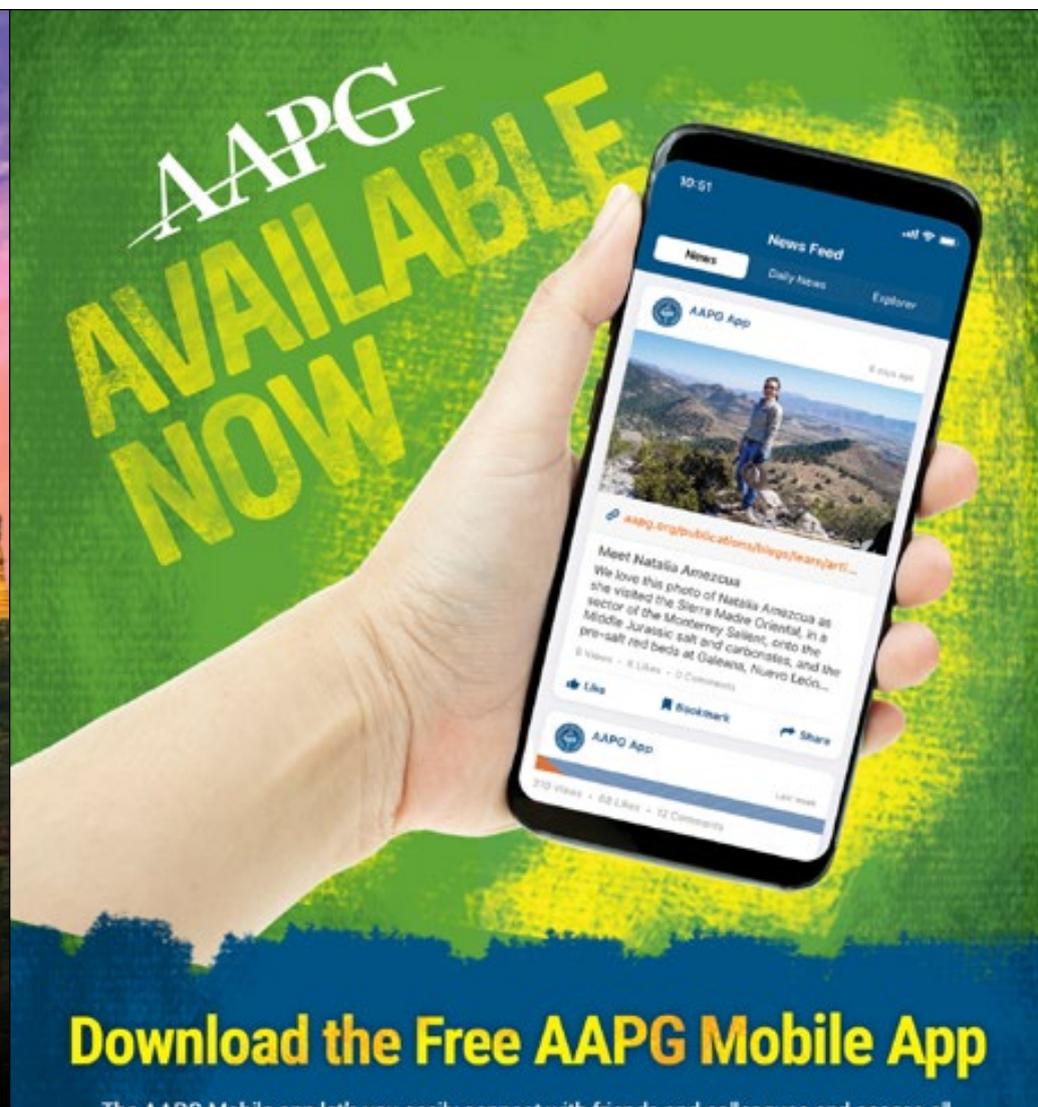
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YP Connect

Opportunity Created in the Wake of Middle East GEO Postponement

Everything was set for AAPG, EAGE and the Society of Exploration Geophysicists to hold the 14th Middle East Geosciences Conference and Exhibition in March 2020 in Manama, Bahrain.

Like other organizers, the Young Professional and Student Committee worked hard to implement a rich and interactive week-long program for students and young professionals of various international institutions and organizations. The Committee, composed of YPs representing the three technical geoscience societies and from several companies and sponsors in the region, detailed an entire program under the financial sponsorship of Saudi Aramco's Exploration Organization.

What Was To Be

While working for the better part of 2019, the Committee focused on delivering a uniquely versatile program ranging in technical sessions, core workshops, resume writing courses, student competitions (AAPG IBA/EAGE Geo Quiz/SEG challenge bowl), a treasure hunt, and a geologic field trip. Alongside the program's technical richness, another key aspect was development of networking skills.

"One of the core elements of any successful conference is networking and the exchange of ideas" said Committee member Othman Matar. "Many long-lasting relationships are forged during these conferences and the Young Professional and Student Committee ensured that each of our events did just that." This was especially highlighted in the Meet-and-Greet event dedicated to network, discuss, and establish mentorship opportunities.

The program was set to receive 200 middle and high school students and 90 university students from prominent institutions in Egypt, Lebanon, Jordan, Iraq and Gulf countries including Saudi Arabia, United Arab Emirates, Kuwait and Oman. Additionally, as a collaborative initiative with King Abdulaziz University, the program planned to inaugurate the first-ever pop-up museum of minerals and rocks from Saudi Arabia. The last day of the program planned to host a day-long Energy Education session for more than 100 teachers from the Kingdom of Bahrain. Facilitated by YPs, the session would have focused on utilizing everyday materials available in any household to understand and teach scientific oil and gas concepts via experiments.



Hala A. Alwagdani is an exploration geoscientist with Aramco's Exploration Organization. Alwagdani obtained dual bachelors' in geology and in Middle East and North Africa studies from the University of Arizona. She is currently the Young Professional and Student Chapter chair for the Middle East Region.

A Setback Becomes an Opportunity

Sounds great?

Well, it would have been, had it happened. What I am about to report is all too familiar to everyone.

Two weeks before the conference date, the pandemic was emerging as a serious concern, consequently postponing the conference to October 2021.

In a world of cancelled everything and seemingly long postponements, the Committee faced many challenges, yet capitalized on rare opportunities to reach out much farther than they had originally planned. As the dust was settling into a new and safer virtual existence, the Committee launched more learning outlets for students and YPs, including the flavor-of-the-day technical webinars.

In addition, they are eager for the soon-to-be-launched Wiki Challenge Write-Off: a student and YP write-off competition promoting research in oil and gas-related technical content for further incorporation in the AAPG Wiki page.

"The AAPG Wiki Challenge is one of the very special efforts done by the Committee. Not only does it help develop the participants' technical knowledge, but it has immediate substantial results that would go on to serve the entire petroleum geoscience community for years on end," explained Committee member Dana AlJishi

For details on the Wiki Challenge, stay posted on AAPG Middle East and GEO's social media accounts.

Even within uncertain times, it was certain the Committee would make the most for students and YPs. Committee member Julian Chenin commended the team's ongoing momentum.

"At the beginning, I was shocked and frustrated when I heard about the postponement of GEO, but with the team's spirit I realized we just started an unstoppable rocket" he said. "Pushing the limits and experiencing new challenges is what makes us stand strong."

With tremendous effort and outstanding volunteerism, the Committee further pushed the advancement of knowledge during these unprecedented times. While managing many virtual events and competitions, they look forward to and are still committed to drive the main event to success in October 2021. 

GEO
Middle East Geosciences
Conference and Exhibition
Conference: 4 - 7 October 2021
Exhibition: 5 - 7 October 2021
Bahrain International Exhibition & Convention Centre

CALL FOR PAPERS

ABSTRACT SUBMISSION DEADLINE: FEBRUARY 28, 2021
Submit abstracts using meeting website: www.aapgmcs2021.org

The Tulsa Geological Society and the AAPG-MCS invite abstract submissions for the 2021 Conference. We welcome both Posters and Oral presentations; here are the technical themes and some of the session we suggest (please see the website for the full list):

<p>GEOLOGY OF THE MID-CONTINENT</p> <ul style="list-style-type: none"> • One Hundred Years of Discovery: Giant Fields of the Mid-Continent • Sedimentology, Stratigraphy, and Reservoir Characterization • Structure, Tectonics and Geomechanics • Petrophysics: Applications and Innovations 	<p>GEOPHYSICS OF THE MID-CONTINENT</p> <ul style="list-style-type: none"> • Advances in Seismic Reservoir Characterization and Imaging • Seismic: Latest Technology Developments • Induced Seismicity in the Mid-Continent
<p>ENERGY EVOLUTION: FUTURE OF ENERGY-21ST CENTURY AND BEYOND</p> <ul style="list-style-type: none"> • Application of Data Analytics, Machine Learning, and AI to the Petroleum Industry • Carbon Capture and Sequestration • Energy Minerals, Alternate Resources, and Mining the Mid-Continent for REEs • Climate Change, Sustainability and the Challenges Ahead 	<p>THE NEXT AGE OF MAKING A PROFIT IN THE MID-CONTINENT</p> <ul style="list-style-type: none"> • Back to the future: Making Money in Conventional Plays • Unconventional Plays: What worked, what did not, and why? • Transition Zones: Identification and Exploitation • Hydraulic Fracture Stimulation: Advances, Challenges, and the Prospect of Re-stimulation

FOR ADDITIONAL INFORMATION, CONTACT: Tara Benda, General Chair - aapgmcs2021@outlook.com
Amy Cose and Tim Phillips, Technical Program Co-Chairs - aapgmcs2021@outlook.com

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AAPG
Latin America & Caribbean Region

COLOMBIA 2021
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ASOCIACION COLOMBIANA DE GEOLOGOS Y GEOFISICOS DEL PETROLEO

Virtual Event
17-18 March 2021

Exploration and Development in Southern Caribbean Frontier Basins

Technical Sessions:

- Tectonic Setting and Petroleum Systems
- Recent Discoveries and New Plays
- Enhanced Imaging and AVO/DHI
- Seismic Acquisition, Risk Reduction and Drilling Optimization

Panel Discussion:

Government-Industry Strategies to Support Colombia's Energy Sector



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For additional information and sponsorship opportunities visit

aapg.to/colombia2021

REGISTER NOW



Director's Corner

An Opportunity in Disguise?

First there was Peak Oil, the Malthusian fear that the world was running out of oil. This idea has been around for a long time but had its most recent renaissance in the mid-2000s with a host of books warning that global demand was going to overwhelm the industry's ability to supply.

The expansion of unconventional oil and natural gas production quieted concerns about supply constraints. The world is not running out of hydrocarbons.

More recently industry insiders have introduced the concept of Peak Demand. As economies mature, they generally become less energy-intensive as economic activity shifts from manufacturing to services. Combined with policy drivers and economic incentives encouraging greater energy efficiency, developed economies are generally using less energy to generate each additional unit growth in economic output.

This isn't true everywhere, with developing economies continuing to see strong demand growth. But in aggregate, as the world becomes wealthier, demand forecasts are flattening – it's not a sharp peak, but rather a plateau.

That concerns industry executives. Because in a world awash in oil and natural gas combined with softening demand, the task of allocating capital to generate returns for your shareholders becomes tricky. And even attracting capital becomes challenging when the market sees little upside opportunity.

Growing Oil Demand Shock

And then arrives COVID-19 and a global pandemic, which "has created the largest oil and gas demand shock in

This is a conundrum. On the one hand there is continued demand for oil and natural gas – no forecasts suggest otherwise – and even if demand levels don't increase significantly, we still have to replace the volumes consumed each year.

history."

Last December 2020, the Boston Consulting Group and the International Energy Forum issued a report titled "Oil and Gas Investment in the New Risk Environment," warning that the dramatic decrease in upstream investments could set the stage for Peak Investment and a future oil supply shock.

This report is a collaborative effort by BCG, a global consultancy, and IEF, an international organization consisting of the energy ministers from 70 producing and consuming nations. IEF has more member countries than OPEC and the IEA combined, representing all corners of the globe.

As all of us know, the industry has been slashing costs in response to the downturn, cutting capital expenditures. But the report suggests that "these lower capex levels appear to be insufficient to deliver the volumes of oil and gas needed to maintain market stability." The fear is that as the world economy recovers post-COVID, growing demand will generate supply constraints, increased market volatility, and end up undermining economic recovery and global energy security.

The reduction in capex in the previous downturn from 2014 to 2015 was 28 percent. Capex continued to fall in 2016 and then remained relatively stable until 2019. But as the impact of

COVID-19 rippled across the world, the industry cut capex in 2020 an additional 34 percent. The result is that "every dollar of 2020-2021 capex that is cut will have twice the impact in reducing activity that cuts made after the 2014 price fall had."

In fact, the IEF and BCG suggest that investment must increase 25 percent per year from 2020 levels for the next three years to avoid crisis, with far more investment by 2030 to assure stable energy markets.

Where Will Investment Come From?

As President Biden issued an executive order on his first day in office rescinding the permit for the Keystone XL pipeline, this need for investment was on my mind. It's a decision that hurts Canada, the United States' largest trading partner; it hurts U.S. workers, it hurts AAPG members – particularly in Canada, and it constricts the ability for vital energy resources to get to global markets.

Yes, many countries have set goals to reduce carbon emissions and promised to accelerate the adoption of lower-carbon energy technologies, but the availability of energy supplies when needed – energy security – is strategically important. It has to be a priority and it requires investment.

But where is this investment going to come from?

The report identified four factors affecting the industry's ability to secure capital:

- ▶ Investor and regulatory requirements for oil and gas producers to reduce the carbon intensity of their operations is a growing constraint.

- ▶ Companies considering a shift from E&P to a broader, more integrated energy business are choosing to allocate capital away from upstream projects.

- ▶ Private equity and other sources of capital investing in oil and gas, particularly unconventional resources are demanding a real return on their investments.

- ▶ All-time high debt levels are limiting the ability of companies to secure capital at competitive rates in order to make further investments.

This is a conundrum. On the one hand there is continued demand for oil and natural gas – no forecasts suggest otherwise – and even if demand levels don't increase significantly, we still have to replace the volumes consumed each year. But the upstream investments needed to do so are dropping, and the capital for these investments is harder to secure.

I call it a conundrum, because there's no simple answer, and the IEF and BCG don't try to offer one. Their purpose is to call attention to the problem and its potential repercussions. But what if that old chestnut is true, and each problem is an opportunity in disguise?

By URSULA HAMMES, EMD President

Divisions Report: EMD

EMD Outlook for 2021

Happy new year to all Energy Minerals Division and AAPG members!

T.S. Eliot wrote, "For last year's words belong to last year's language, and next year's words await another voice. And to make an end is to make a beginning."

Therefore, I am focusing on the exciting future outlook in energy minerals and not dwelling on the past year that has been painful to many of us on a personal and professional level. One of the good outcomes of the downturn in oil and gas was an increased focus on alternative resources and technologies related to both the climate change discussion and the demand for clean energy. The transition has been embraced by most major oil and gas companies, which already have a competitive advantage in producing energy related to low-cost production and significant domestic expertise. Perhaps most exciting is the fact that many of the majors have been putting out statements of diversification



HAMMES

The oil and gas industry as we've known it is in flux, but with that, many new opportunities will present themselves.

toward clean energy, many with a goal of net-zero by 2030!

However, this transition will not happen without hydrocarbons, especially natural gas. EMD is very well prepared to lead the charge with our different scientific committees focused on alternative energy sources, such as nuclear, critical minerals, gas hydrates, helium, geothermal and tight oil and gas. In order to facilitate the energy transition, the oil and gas sector will need to work together with companies and scientists involved in

critical minerals, hydrogen, geothermal and others, as these industries will also furnish jobs and attract investments and growth opportunities. Unfortunately, the oil and gas industry as we've known it is in flux, but with that, many new opportunities will present themselves.

ACE 2021 and Other EMD Content

Preparations for the 2021 AAPG Annual Convention and Exhibition are under way with a variety of very interesting sessions in the works.

Claudia Hackbarth is the chair for Theme 9 of the meeting and it's not too late to submit your abstracts. We are also going to have another "What's new in energy minerals" special session with our esteemed EMD committee chairs giving us an overview of the newest developments in their respective committees, in addition to a session on "Questions of transitions – forum of leading thinkers." Stay tuned!

I hope you didn't miss the EMD highlights and special section on our Uranium and Hydrate committees in the last issue of the EMD. Please check out our new EMD YouTube channel showcasing highlights and diverse sessions of our EMD activities, which can be found by searching "AAPG Energy Minerals."

As always, please contact me or any of the EMD committee chairs if you'd like to get involved in this exciting organization by visiting AAPG.org/Divisions/EMD.

The Best Insights and Opportunities to Help Develop Your Skills and Knowledge

ONLINE TRAINING

AAPG Geosciences Technology Workshop – 2nd Edition: Decision Based Integrated Reservoir Modeling

Web-Based Participation | 1–2 Feb. 2021
Following the successful 1st edition of the Decision based Integrated Reservoir Modeling GTW, the 2nd edition will focus on the latest technology and cost-effective approaches for building accurate and predictive 3-D reservoir models for the oil and gas industry. Integrated reservoir modeling plays a pivotal role in the E&P workflow, where 3-D quantitative geocellular models provide essential input for major oil and gas field development decisions. Static and dynamic data integration, new developments in 3-D reservoir modeling techniques, and uncertainty quantification associated with reserves estimation, will be just a few topics, among others, to be tackled and discussed during the workshop.

AAPG Geosciences Technology Workshop – 2nd Edition: Maximizing Asset Value: Integrating Geoscience with Reservoir Management & Facilities Optimization

Web-Based Participation | 22–24 Feb. 2021
The objective of the workshop to drive a further discussion of integration processes between geoscience, engineering, and technology deployment through examining the industry's case studies across multiple disciplines. The workshop also aims to highlight the improvements made in the topic over the last two years across both conventional and unconventional field development.

APPEX 2021

Web-Based Participation | 1–4 Mar. 2021
APPEX is where integral deal makers go to close deals, network with the right people, and get the latest global prospecting updates. Whether you are looking to buy, sell or farm out E&P deals, expand into new areas, find new partners, make high quality contacts, or stay on top of what's happening in the industry, APPEX is the place to be.

AAPG Geosciences Technology Workshop – Immersion into Shuaiba Formation to Maximize Production

Web-Based Participation | 8–11 Mar. 2021
The workshop will focus on the Aptian section of the Arabian Plate and will cover one of the main reservoirs in Thamama group (Shuaiba Formation). This part of the stratigraphic column is one of the most diverse regional stratigraphy which was likely the result of segmented basinal physiography during that time.

AAPG Geosciences Technology Workshop – Exploration and Development in Southern Caribbean Frontier Basins

Web-Based Participation | 17–18 Mar. 2021
The two-day workshop brings together technical experts and industry leaders from Colombia and throughout the Americas to take a multidisciplinary look at future opportunities for exploration and development of Southern Caribbean Frontier Basins. The workshop offers participants the opportunity to experience Colombian coastal culture in a city positioning itself to be the Caribbean's premier offshore destination.

AAPG Geosciences Technology Workshop – Advanced Petroleum Systems Analysis in the Asia Pacific Region: New Technology and Applications

Web-Based Participation | 17–18 Mar. 2021
This workshop will focus on advances made in petroleum systems analysis as a predictor of hydrocarbon presence, new technology and applications, and future directions of this important geological tool.

International Petroleum Technology Conference (IPTC)

Web-Based Participation | 23 Mar.–1 Apr. 2021
IPTC is focused on the dissemination of new and current technology, best practices and multi-disciplinary activities designed to emphasize the importance of the value chain and maximising asset value. The knowledge, capabilities and strengths of the participating countries and the sponsoring societies global membership, over the spectrum of multi-disciplinary technologies, are central to the success of the conference and the corresponding exhibition.

AAPG Geosciences Technology Workshop – 3rd Edition: Stratigraphic Traps of the Middle East

Web-Based Participation | 28 Mar.–1 Apr. 2021
The workshop is an opportunity for attendees to receive up-to-date knowledge about stratigraphic trap exploration, exposure to regional and global stratigraphic case studies, and to be introduced to state of the art-technologies utilized to detect these difficult to find yet rewarding traps. It is an opportunity to network and share experiences. The participants will receive a summary of the breakout sessions and discussions, lessons learned, and the abstracts of papers presented in the workshop.

Mexico Offshore Exploration Summit

Web-Based Participation | 13 Apr. 2021
Join operators working in the Mexican offshore for an executive-level event highlighting results of recent exploration campaigns and reviewing strategies for 2021 and beyond. This one-day, high impact virtual event includes panel discussions and Q&A with operators and special presentations by Mexico's National Hydrocarbon Commission (CNH Mexico) and the Mexican Hydrocarbon Association (Amexhi).

AAPG Geosciences Technology Workshop – High CO₂, High Contaminant Challenging Fields and Alternative Energy - Impact and Monetization

Web-Based Participation | 23–24 Nov. 2021
High CO₂ fields and marginal fields (due to high levels of contaminants) are some of the challenges that are prevalent in the Asia Pacific petroleum industry. Join AAPG Asia Pacific for a two day workshop focused on best practices, risk-based planning and the role geoscientists and engineers will play in these changing times.

AAPG Geosciences Technology Workshop – Source Rocks of the Middle East

Bahrain | 22–24 Mar. 2021
Save the date. Join us for the Source Rocks of the Middle East. More information coming soon.

AAPG Carbon Capture, Utilization, and Storage (CCUS) Conference: An Emerging Field for Petroleum Geologists

Sugar Land, Texas | 23–24 Mar. 2021
Plan now to attend AAPG's Carbon Capture, Utilization, and Storage (CCUS) Conference 23–24 March 2021 in Sugar Land, Texas at the Sugar Land Marriott Town Square. Themed "An Emerging Field for Petroleum Geologists," the conference will highlight current CCUS work and tackle related challenges, including: subsurface storage in saline reservoirs, storage associated with CO₂ enhanced oil recovery, reservoir monitoring and risk assessment, case studies, industry applications, economics, incentives, policy, and more.

AAPG Geosciences Technology Workshop – Exploration and Development of High Pressure and High Temperature Reservoirs

Kuwait City, Kuwait | 5–7 Apr. 2021
Join us for the Exploration and Development of High Pressure and High Temperature Reservoirs. More information coming soon.

AAPG Geosciences Technology Workshop – Evaporite Processes and Systems: Integrating Perspectives

Salzburg, Austria | 14–15 Apr. 2021
The aim of this workshop is to improve our understanding and predictive ability by addressing evaporite systems in an integrated manner, all the way from precipitation to structuration, and exploring the multiple properties of evaporite sequences.

AAPG Geosciences Technology Workshop – Well Planning and Delivery in Unprecedented Times

Geneva, Switzerland | 21–22 Apr. 2021
This workshop will bring together specialists from across the disciplines from IOCs, NOCs and service providers as well as academic and independent researchers involved in early well planning through to delivery to identify key factors that play a role delivering wells in a safe, timely and cost effective manner.

AAPG Annual Convention and Exhibition (ACE) 2021

Denver, Colorado | 23–26 May 2021
The American Association of Petroleum Geologists invite you to join us for the AAPG Annual Convention and Exhibition (ACE), 23–26 May 2021 in Denver, Colorado, USA. Call for abstracts are now being accepted. Don't miss your chance to participate, submit today.

AAPG Geosciences Technology Workshop – Mixed/Hybrid Systems (Turbidite, MTDs and Contourites) on Continental Margins

Lisbon, Portugal | 25–26 May 2021
This two-day conference aims to bring together diverse experts working on modern and ancient turbidite, MTDs, contourite and hybrid/mixed systems in order to improve the present-day knowledge, models and predictive power.

Unconventional Resources Technology Conference (URTeC) 2021

Houston, Texas | 26–28 Jul. 2021
Jointly organized by SPE, AAPG, and SEG, URTeC connects the key technical and business professionals deciding where, how and when plays will be developed and wells drilled every day. It's the only event leveraging expertise from all technical backgrounds and focusing on the asset team approach to successful field development.

AAPG Geosciences Technology Workshop – Structural Styles and Hydrocarbon Prospectivity in Thrust Belt Settings Around Europe and North Africa

Barcelona, Spain | 7–8 Sept. 2021
The Workshop aims at bringing together experts from academia and industry on different disciplines to share experiences, new approaches, new data and new ways of integrating information that can help in reducing the uncertainties related to the exploration activities in Europe and North Africa Thrust Belt Systems.

AAPG Geosciences Technology Workshop – Integrated Process-Based Geological Modeling in Exploration and Production

Abu Dhabi, United Arab Emirates | 27–29 Sept. 2021
Join us for the Integrated Process-Based Geological Modeling in Exploration and Production workshop. More information coming soon.

Energy Opportunities Conference 2021

Mexico City, Mexico | 29 Sept. 2021
AAPG and Energy Projects Forum (EPF) invite you to participate in the Latin America and Caribbean Region Energy Opportunities Conference to be held at the Camino Real Polanco in Mexico City. The 2021 Conference builds on the success of Energy Opportunities 2018, when industry and government leaders representing 86 companies and 21 countries met in Cartagena, Colombia to learn, network and explore business opportunities in the region's energy sector. This executive-level conference combines high-level plenaries featuring world-renowned industry leaders and innovators with topical workshops covering finance, technology and the environment.

GEO: 14th Middle East Geosciences Conference & Exhibition

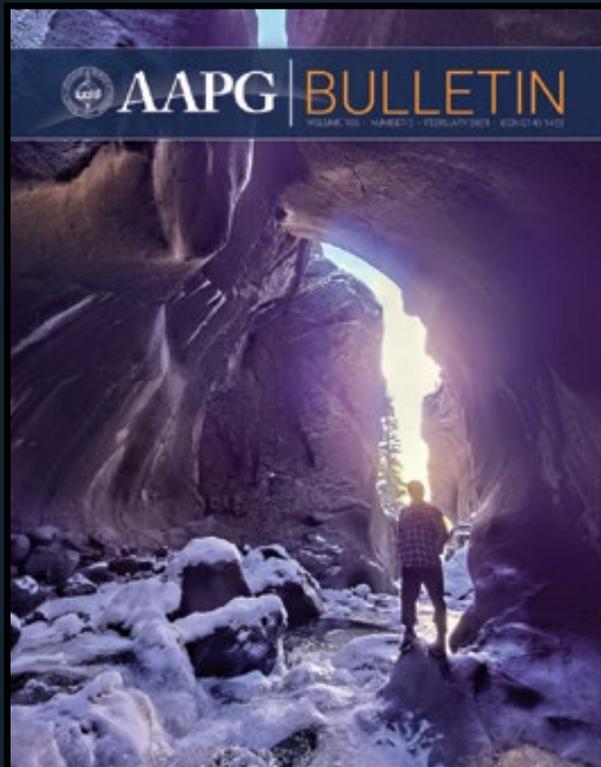
Manama, Bahrain | 4–7 Oct. 2021
For 26 years, the GEO exhibition and conference has been at the forefront of petroleum geoscience. GEO has fast become a next generation energy event, hosting major NOCs, IOCs, manufacturers, technology providers and service companies – all of whom play an active role in the global energy value chain.

AAPG/EAGE 5th Myanmar Oil & Gas Conference

Yangon, Myanmar | 9–11 Nov. 2021
Continuing on from our highly successful fourth geological conference in November 2018, AAPG and EAGE have great pleasure in organizing a fifth conference in Yangon, 9–11 Nov. 2021. This conference will provide the opportunity to understand the significant progress made over the last 24 months and network and share experiences with colleagues.

AAPG | BULLETIN

Read Up on the Latest in Geoscience



Recognized as one of the most respected, peer-review technical journals in existence, the AAPG Bulletin provides our geoscience community with the latest research, science, and information as it relates to petroleum, natural gas, other subsurface fluids, and mineral resources.

See the February 2021 AAPG Bulletin content online now. Articles for this issue are listed below. To view an article abstract, scan the QR code with your mobile device. A login is required to view the entire article. Locate the login options under "Welcome Guest" in the top right corner of the abstract viewing screen.

E&P NOTE

Life span of oil reservoirs: Examples from three old reef pools in Alberta, Canada

Mengwei Zhao



GEOHORIZON

Induced seismicity risk management: The problem of disappearing faults

Doyle R. Watts, Ernest C. Hauser, Mohammad Mohshin, and David F. Dominic



ARTICLES

Origin and charging histories of diagenetic traps in the Junggar Basin

Jianguo Pan, Guodong Wang, Yongqiang Qu, Wen Qi, Lu Yin, Duonian Xu, Tuanyu Teng, Bin Wang, Kaijun Tan, and Linjun Huang



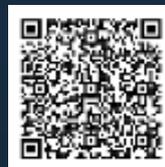
Experimental determination of porosity and methane sorption capacity of organic-rich shales as a function of effective stress: Implications for gas storage capacity

Garri Gaus, Reinhard Fink, Alexandra Amann-Hildenbrand, Bernhard M. Krooss, and Ralf Littke



Brittleness modeling selects optimum stimulation zone in shaly source rocks in the Whangai Formation, New Zealand

Claudio Rabe, Raul Correa Rechden Filho, Jesus Pastor Salazar, Fernando Della Pasqua, Giovanni Chaves Stael, and Luiz Antonio Pierantoni Gamboa



Multiple thrust detachments and their implications for hydrocarbon accumulation in the northeastern Sichuan Basin, southwestern China

Chuanxin Li, Dengfa He, Guo Lu, Kai Wen, Abijah Simon, and Yanpeng Sun



Characterization of five unconventional diatomaceous (opal-A) reservoirs, Monterey Formation, San Joaquin Valley, California

David K. Larue, Christian Hager, Thomas Merrifield, Gena M. Evola, David Crane, and Phillip Yorgensen



Fractal characteristics of pore networks and sealing capacity of Ordovician carbonate cap rocks: A case study based on outcrop analogues from the Tarim Basin, China

Jun Wu, Tailiang Fan, Enrique Gomez-Rivas, Anna Travé, Zhiqian Gao, Shanshan Wang, and Xiaolong Sun



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