

### Reading Rocks to Find Energy

Crushing, Melting and Analyzing Rock Samples Helps Interpret Complex Geology and Find More Oil and Gas

Exploring the globe for natural gas and crude oil, geologists have long relied on seismic waves and fossils for clues. Now, Chevron's earth detectives are also reading the rocks with chemical fingerprinting to help ensure that major new projects in Australia and the Middle East produce as much energy as possible.

"Rocks are made of minerals, and minerals are made of elements," explained Paul Montgomery, a Chevron geologist and expert in chemostratigraphy, which uses laser mass spectrometry to scan tiny rock samples for traces of 50 elements — lithium, argon, iridium, xenon and others.

"It helps us correlate oil and gas reservoirs across hundreds of kilometers," he said. "We can better understand what we might find when drilling in any direction and how the reservoirs will behave and express themselves."

When integrated with other techniques for interpreting the subsurface, chemostratigraphy is an especially valued tool for understanding the disjointed stacks of gas-rich sandstones discovered by Chevron in the mighty Mungaroo Formation beneath the Indian Ocean off northwestern Australia. Tapping this resource, the Chevron-led Gorgon and Wheatstone projects are expected to provide future supplies of liquefied natural gas to help meet fast-rising Asia-Pacific demand for cleaner energy.

Much more than elsewhere, Chevron needs chemostratigraphy to optimize Gorgon and Wheatstone, two of Australia's largest-ever industrial projects, forecast to cost \$66 billion. Because for all its potential, "the complex Mungaroo Formation lacks good fossil markers. Geologic correlation here is like trying to picture an entire castle from within a single room," said Montgomery.

"Also, seismic surveys yield imperfect information on how the reservoirs are connected. Chemostratigraphic techniques can greatly enhance our understanding," said Montgomery. "It's absolutely critical to the long-term performance of these deepwater gas fields that we drill just the right number of very large wells at precise locations and depths. We need these wells to run great for 30 years."

Chemostratigraphy also provided new insights on the mammoth First Eocene oil reservoir at Wafra, in the Partitioned Zone between Saudi Arabia and Kuwait, where Chevron is targeting 6 billion barrels of potentially recoverable oil with steam-injection technology. Chemical fingerprinting helped confirm a geologic profile built

Darcy De Leon 7/9/2015 9:27 AM

**Comment [1]:** As per AP Stylebook's "dash" entry:

"WITH SPACES: Put a space on both sides of a dash in all uses except the start of a paragraph and sports agate summaries."

Darcy De Leon 7/9/2015 8:55 AM

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from alternative data, demonstrating that chemostratigraphy, coupled with other techniques, can provide the detailed stratigraphic correlation needed for a successful Wafra steamflood.

In the United States and Eastern Europe, chemostratigraphy will help Chevron develop new supplies of gas from shale, which is difficult to analyze using fossils. Oil and gas projects in Angola, the U.K. Atlantic Margin and other locations have also benefited, said Montgomery. "Everywhere we've used this technology, it has added to our success."

Mapping geology with mineral clues such as color isn't new, but, in the past decade, better, faster spectrometry has made chemostratigraphy a more accessible and affordable tool, said Montgomery. Still, the surveys require months of work on drilling rigs, in laboratories and in technical centers where geoscientists interpret the mineral DNA.

A recent major survey for Gorgon, for example, collected and scanned some 1,500 samples from eight wells — a total of 75,000 element profiles. Chemostrat Ltd. analyzed the samples for Chevron by sampling tiny rock cuttings brought up from different depths during drilling.

Technicians painstakingly labeled, sorted, washed, crushed and heated the samples for the laser spectrometer, which measures light wavelengths to reveal the varied chemical personalities of different rock layers. The result: nine chemostratigraphic packages, 22 geochemical units and 19 sand units to help Chevron geoscientists map 30 million years of depositional history from prehistoric rivers during the Triassic Period, about 200 million years ago.

In this lost world, sand, silt and organic matter accumulated in channels and deltas across a steamy, sprawling landscape now buried thousands of meters beneath the ocean floor. Shales leaked hydrocarbons into the Mungaroo's sandstone sandwich, and huge blocks slid up and down, creating a formidable puzzle of fault blocks and pinched-out layers.

Fortunately, Mother Nature left her chemical fingerprints to help Chevron best develop a vast storehouse of Australian gas — and no doubt, many other energy treasures ahead.

Darcy De Leon 7/9/2015 9:25 AM

**Comment [2]:** Set off the nonessential prepositional phrase with commas, as per the AP Stylebook's comma entry:

"WITH NONESSENTIAL CLAUSES: A nonessential clause must be set off by commas."

Darcy De Leon 7/9/2015 8:59 AM

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Darcy De Leon 7/9/2015 9:09 AM

**Comment [3]:** Use a comma to separate two independent clauses, as per the AP Stylebook's "comma" entry:

"As a rule of thumb, use a comma if the subject of each clause is expressly stated: We are visiting Washington, and we also plan a side trip to Williamsburg. We visited Washington, and our senator greeted us personally."

Darcy De Leon 7/9/2015 9:01 AM

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