

Shale Holds Huge Potential for Researchers at Universities

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A simple question, “Can you tell us about shale?” has spawned growing research programs at universities around the globe.

In less than five years, industry-supported university research has played a key role in defining the structure and elements in shale. The work in a group of laboratories at the University of Oklahoma (OU) in Norman, Oklahoma, is an example of the competitive drive to understand these challenging rocks.



Postdoctoral fellow Mark Curtis prepares a sample for the focused ion beam scanning electron microscope used to examine the smallest details within shale. He works in the Devon Nanolab with equipment donated by the oil company in 2010.

Now the goal is to explain the inner workings of these rocks and use that understanding to find more oil and gas and produce it far more efficiently.

“The whole thing started with the question: Can you tell us about shale? It is leading into so many interesting areas,” said Chandra Rai, who along with Carl Sondergeld has led the OU lab at the Mewbourne School of Petroleum and Geological Engineering. The pair and a longtime lab manager moved into academia in 1999 when BP donated its petrophysics lab to the university.

At the time, shale exploration was often still seen as little more than an interesting experiment by Mitchell Energy Company in the Barnett Shale around Fort Worth, Texas. During the following decade:

- The lab—renamed the Integrated Core Characterization Center—moved to OU’s main campus in Norman.
- Devon Energy bought Mitchell Energy and showed that drilling horizontal wells could significantly increase shale gas production.
- The industry mobilized to tap the enormous potential in unconventional reservoirs.

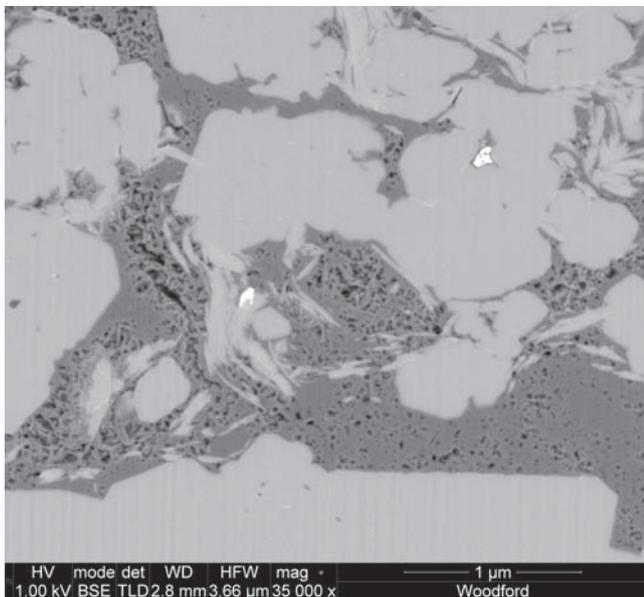
In 2004, Devon’s shale exploration team started seeking more outside advice.

“When we began to look at it, we realized we had some big questions about shale,” said Jeff Hall, vice president of exploration at Devon. On the list were: How does oil and gas move through the rocks to the wellbore? How can we better complete wells in this reservoir? There are big differences in production from well to well. Why is that?

Devon’s shale research led it down a meandering path. It started with a geophysical study that morphed into a geological study that raised engineering questions. Hall said, “We began to realize it is more complicated.”

To begin with, researchers had to find tools capable of looking into the structure of these extremely fine-grained mudstones. When they did, it was clear the name shale covered a variety of things. “People started with the idea that all shales were all the same,” Sondergeld said. “It is amazing when you see the microstructure how different they are.”

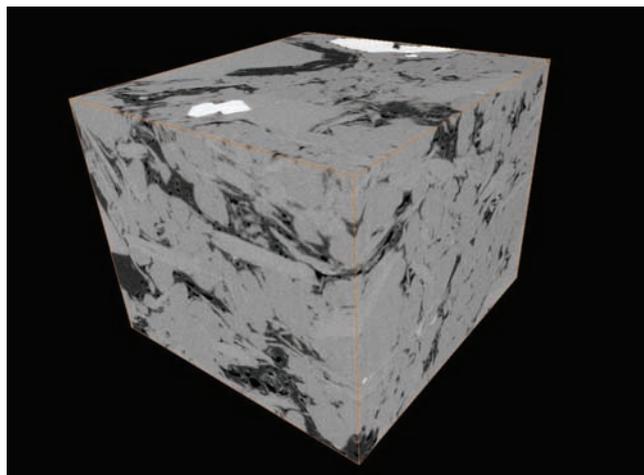
Other companies and universities followed a similar path into shale research. The size of the resource, and the work needed to go after it, are both huge. From the start, the research indicated how unconventional shale reservoirs really are. As the list of questions grew, so did the range of experts involved.



The OU lab uses a dual-beam focused ion beam and scanning electron microscope to create 2D images. The dark gray areas in this tiny sample of Woodford Shale are organic material and the black dots are pores.

“All sorts of approaches are needed and each contributes to the picture,” said Robert Loucks, a professor at the University of Texas at Austin (UT) who was the first to identify kerogen as the source of hydrocarbons in shale. Or as Hall put it, “We never really know where we are going when we ask a question.”

Creating a research department capable of following such an unpredictable path is beyond the means of all but the largest energy companies. Shale research draws from a broad talent pool including experts in petroleum, chemical, and mechanical engineering, geology, sedimentology, stratigraphy, petrophysics, geophysics, and phys-



Hundreds of these cross-sections are precisely stacked to create a 3D digital image. The image replicates the shape of features such as pores and also can be analyzed to determine the minerals and organic materials within.

ics, as well as computer programming. Industry-backed shale research groups have grown up at UT, Penn State University, Colorado School of Mines, and Texas A&M University. The University of Leeds in the UK has formed a company-backed shale research group, and work is ongoing at universities in Germany and Australia. The industry-supported Gas Shales in Europe effort is managed by a team of four members at GFZ, the German Research Centre for Geosciences in Potsdam. There are two other national research institutes and six European universities involved in the effort.

In Australia, CSIRO—the Commonwealth Scientific and Industrial Research Organisation—has a shale research group that also draws on works from the country’s universities.

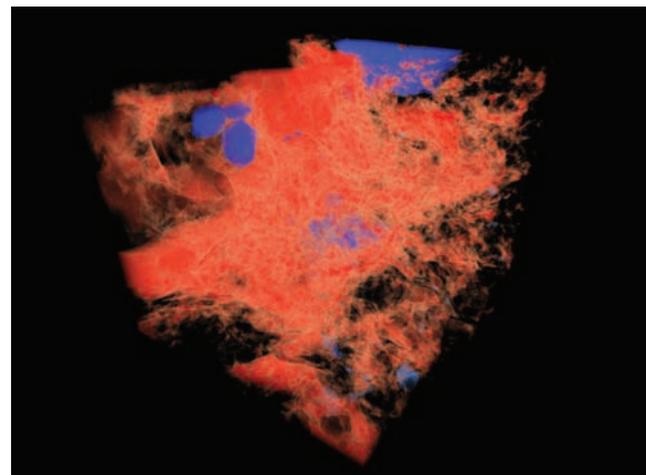
Hall said the USD 22 million that Devon invested in the OU lab has helped it reduce the risk of moving into frontier shale plays before others, pick better well locations, and improve its ultimate recoveries. “Devon invested some significant money in that lab and we feel like we have gotten a great return on that investment,” Hall said.

Finding Ways to Look Inside

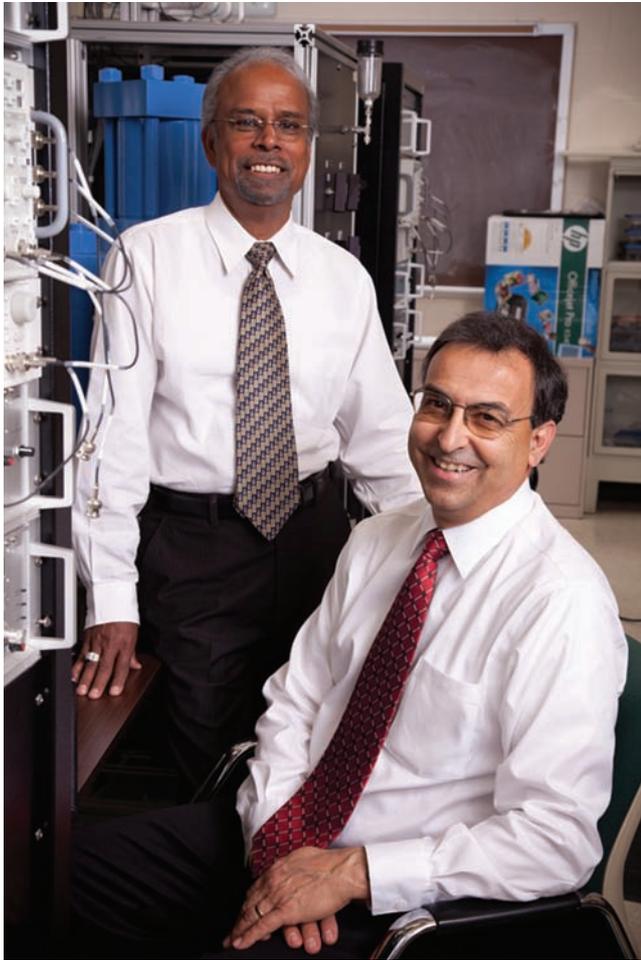
Shale offers researchers the opportunity to work in a frontier field. It is an intensely competitive place to be. The OU lab has been particularly focused in core analysis. Sondergeld is constantly adding new equipment, often designed to its specifications, to the stay on the edge in rock analysis.

“On this work, he is way ahead of the industry,” said Kent Newsham, senior technical adviser at Apache, also a major OU backer. But in shale research, a six-month lead is considered big, and is not likely to last. Money put up by companies backing shale research is commonly called an investment. New ideas from the labs are competing with real world experience in shale exploration, which was developed largely by using what has been learned from drilling thousands of wells.

Sondergeld predicts that research will lead to more efficient methods. His mantra: less horsepower, less water, and less



Images can be segmented to highlight key features. The orange area shows the organic material and its pore network, and the blue colored section is pyrite.



Chandra Rai, left, and Carl Sondergeld have built the shale research program at the Mewbourne School of Petroleum and Geological Engineering at the University of Oklahoma.

sand. Rai predicts that in five years, reservoir simulators will have new physics incorporated into the flow modeling.

Steve Rupel, project director of the Mudrock Systems Laboratory at UT, said its multidisciplinary research work will change geophysical tools and reservoir models, allowing explorers to target the most productive spots. At UT, much of the work is aimed at taking a granular understanding of the shale and applying it on a large scale, with goals such as a better understanding of the shale formations, and improved well logging tools to analyze it.

Texas A&M's Halliburton Center for Unconventional Resources is investigating shale gas reservoir modeling, reserve estimates and rock properties. It is also doing research in tight sands—long a focus at A&M—heavy oil, coalbed methane and gas hydrates.

The Colorado School of Mines focuses on oil shale—the kind that must be heated to extract the oil—as well as the shale in the nearby Niobrara and the Bakken producing oil and gas after fracturing.

Penn State's research grew out of a long knowledge of the economic geology of the region, dating back to the early work in the 1970s that looked into producing gas from

coal seams. A 2008 estimate of the potential reserves there by Penn State geosciences professor Terry Engelder helped spark interest in exploring the Marcellus Shale. "We are more or less using different lanes," said Torgay Ertekin, a professor of petroleum and natural gas engineering at Penn State. "In one way or another we hope these lanes will connect and merge with each other."

Building New Research Tools

The OU shale research program now draws on the work of more than 10 faculty members with a staff of 25 students—most of them graduate students—a lab manager, three lab technicians and a computer programmer. The support pays for a full-time research faculty member on staff.

A tour of the lab includes frequent stops at new devices. There is the micromechanical tester, a device that is little bigger than a textbook. The device is capable of simulating the pressure in formations deep underground on a rock sample. It is small enough to fit inside a scanning electron microscope used to image the samples.

There are computer programs capable of simulating the impact of such pressure: but, Sondergeld is constantly looking for ways to verify what is assumed. There are studies to simulate fractures—some cracks do not look as commonly expected—and a study of microseismic activity during a simulated fracture job suggests the number of fractures peak prior to the maximum pressure point.

Many of the experiments require new methods and hardware. "Carl is unique," Newsham said. "He is a good theorist and experimentalist, which is rare. And he can build the equipment that is used to run the experiments."

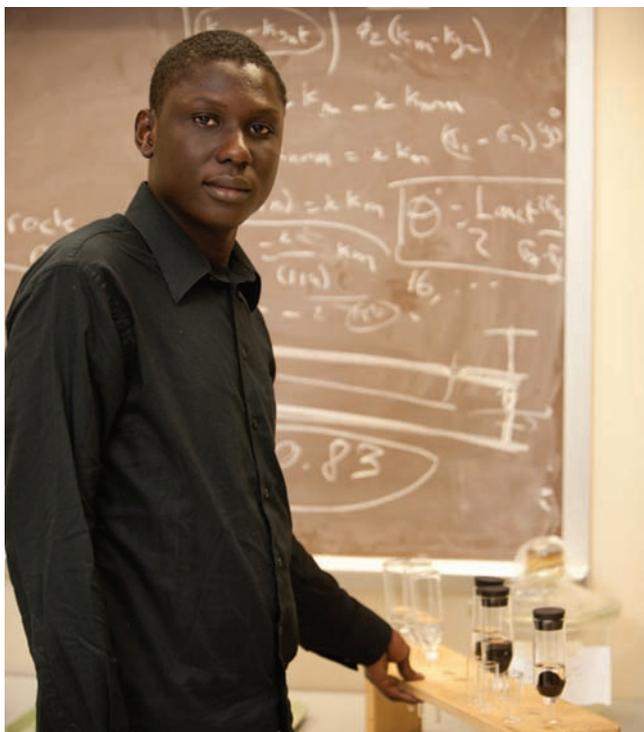
Ali Tinni has taken advantage of that opportunity. The second-year petroleum engineering graduate student has been listed as one of the authors on two papers. He will be presenting another paper at the SPE Annual Technical Conference and Exhibition in Denver this fall. "Everything we do here is pretty much new," said Tinni, who said he spends all his time in the lab. "This is the only lab that has this technology. I can be here at midnight and do 10 different experiments."

Connecting the Big and the Small

Shale research comes in many forms. A frequent theme is scaling up. That is using an understanding of the rock at a microscopic level to tap its potential. The contrasting interests of two OU researchers show the interplay between large and small scale. Yücel Akkutlu takes a micro view of shale while Jeff Callard looks at the macro view.

Akkutlu consider spaces so small they can accommodate only a few methane molecules. Callard builds production curves tracking production from formations often 300 hundred feet thick. Akkutlu, a chemical engineer by training, is studying how gas behaves inside spaces so small that the molecules adsorbed on the pore walls significantly limit the space available for free gas.

On the field scale, Callard, a petroleum engineer who is an assistant professor, is working on curves predicting long-term production decline rates. The goal is to be able to answer questions such as: Will completion methods resulting in the highest initial production reduce the ultimate recovery over the next 20 years?



Ali Tinni is one of 25 graduate students working in the research laboratory at the University of Oklahoma. He uses micromechanical testing that allows him to observe shale deformation in real time with a scanning electron microscope.

Akkutlu's work has described the surprisingly large amount of adsorbed gas residing on the organic pore walls inside shale. This affects Callard's production estimates by changing the total reserves in place, and perhaps the ultimate recovery rate.

Callard's work is based on making use of a wider range of data from shale gas wells. He is tracking a growing number of markers over time, including a variety of gases, oil, and water. For example, over the years as the reservoir pressure

declines, more of the adsorbed gas is expected to flow out. To look for this, Callard is using data from the gas analysis to spot certain methane and carbon dioxide isotopes that indicate the source of the gas is changing.

The studies are revealing the unusual properties of gases in the smallest organic pores in shale. These nanospaces appear capable of providing long-term storage for carbon dioxide far exceeding its capacity for natural gas. Callard said the research points to the importance of how things interact in there: "It is not just the fluid. It is not just the rock. It is the combination," he said.

Learning from Drilling Reports

Oil industry input into shale research does not end when the check is written. The input is both personal and mineral. Experts from partner companies visit regularly. Their questions and observations help guide the work. Houston-based Apache has a petrophysicist who works one-quarter time in the Oklahoma lab. Devon's headquarters is a short drive.

The lab benefits from the rock samples and experience of its partners. "Devon has got this enormous database having drilled thousands of wells. If Carl says you can do it with less horsepower, less water and less sand we can go into the database and we can do those kind of analysis," Hall said.

As more questions are asked, more support is required. As a result, OU has expanded its list of corporate backers, adding ConocoPhillips, Statoil, Total, Encana, and Cimex. It is looking to add up to three more. UT has taken the idea further with 20 companies backing its Mudrock Laboratory.

Long-term supporters Devon and Apache say they are using what they have learned. Devon, which recently announced it leased 750,000 acres in undisclosed frontier areas, did lab work comparing those areas with well-known shales before it moved forward. Apache is using analysis by the lab to determine how it will develop shale reserves in Canada.

"We changed our perspective about what we thought was going on in the rock. From work they did, they said this may not be going on. You should try targeting this," said Hall of Devon. "They were right a lot. We changed our practices as we gained knowledge." **JPT**

For further reading:

SPE 131771-PP • "Micro-Structural Studies of Gas Shales" by Carl Sondergeld, SPE, University of Oklahoma, Ray J. Ambrose, SPE, Devon Energy, Chandra Rai, SPE, University of Oklahoma, and J. Moncrieff, SPE, University of Oklahoma

SPE 134583-MS • "Carbon Dioxide Storage Capacity of Organic-Rich Shales" by S.M. Kang, E. Fathi, Ray J. Ambrose, Yucel Akkutlu, and R.F. Sigal, University of Oklahoma

SPE 130146 • "Reservoir Management in Unconventional Reservoirs" by M.U. Khan, SPE, and Jeff Callard, SPE, University of Oklahoma

SPE 131768-MS • "Petrophysical Considerations in Evaluating and Producing Shale Gas Resources" by Carl Sondergeld, SPE, University of Oklahoma; Kent Newsham, SPE, J.T. Comisky, SPE, and M.C. Rice, SPE, Apache Corp; and Chandra Rai, SPE, University of Oklahoma

SPE 137693-MS • "Structural Characterization of Gas Shales on the Micro- and Nano-Scales" by Mark Curtis, University of Oklahoma; Ray J. Ambrose, Devon Energy; Carl Sondergeld, Chandra Rai, University of Oklahoma

SPE 131772-MS • "New Pore-Scale Considerations for Shale Gas in Place Calculations" by Ray J. Ambrose, Devon Energy and the University of Oklahoma; Robert C. Hartman, Weatherford Labs; and Mery Diaz-Campos, Yucel Akkutlu, and Carl Sondergeld, University of Oklahoma