Oil Shale and New Technologies

Producing energy from rock that burns is entering into a new research and development phase. Can these processes now in the experimental stages unlock some of oil shale's enormous potential?

Thomas Smith, Associate Editor

Oil shale deposits represent staggering resource figures. Estimates by the U.S. Geological Survey suggest a global resource of 3 trillion (10^{12}) barrels of oil, but reasonable estimates as high as 12 trillion barrels have been made. About half of the resource is located in the western United States. However, "resource" figures can be very misleading. They represent the total amount of a given material that is contained in the Earth, in this case the total oil equivalent in the world's oil shale. The important unanswered question is: how much can be economically recovered? What kind of figure can we ultimately use for recoverable resources?

Issues regarding large strip and underground mines, high costs to produce the energy, release of greenhouse and acidic gases, and water requirements have all been deterrents in extracting energy from oil shale deposits. New technologies could change that, making this vast resource economic to exploit and much more environmentally acceptable.

Oil shale has been used as a fuel for centuries. It occurs in many parts of the world including the United States, Canada, Sweden, Scotland, Spain, Estonia, China, Russia, South Africa, Australia, Brazil and France. Some of these deposits have been mined with oil and other minerals being recovered, usually by heating the crushed rock in a process called retorting (see **Geo ExPro v. 1 no. 3**, pp. 26-32 for details about this resource). Peak production occurred in the early 1980's. Now, only Estonia, China and Brazil are mining and retorting oil. China is the only area with projected large increases in production.

Photo: Jeremy Boak; Map: from Smith, 1980

The largest deposits of oil shale in the world are contained in the Green River Formation located in western Colorado, eastern Utah and southwestern Wyoming, United States. The Bureau of Land Management (BLM) estimates 800 Bbo (127 Bm^3) recoverable.

Rock that Burns

Photo: Glenn Vawter

Most oil shale is not true shale nor does it generally contain oil. Technically speaking, most of the deposits in the western U.S. are an organic rich dolomitic marlstone (a mixture of clay, magnesium and calcium carbonate). The solid organic material is kerogen derived from organisms, primarily algae and bacteria. Oil and gas are produced upon heating not unlike many oil reservoirs that need additional heat to produce oil in economic quantities. "Oil shale" was perhaps coined as promotional term by people trying to sell stock in oil shale companies. Anyone who has broken apart these rocks or has scratched the surface and got a smell of the petroleum odor, knows why the term has stuck.

The organically richer oil shale actually burns and these rocks have been set afire by lightning strikes. Ranchers in northwestern Colorado burnt the rock in their fires just like coal. One early settler actually built his fireplace and chimney out of the easily cut and abundant rock. The first fire was the last for his cabin as the fireplace, chimney and finally the whole cabin caught fire and burnt down.

Getting the Oil Out

The U.S. Department of Energy lists 23 companies with oil shale interests; 13 of these are project developers and 17 are technology developers. Newer technologies being developed have 100 years of past efforts to help pave the way and all the technologies involve some type of heating to convert the kerogen to oil and gas. About twice as many companies are developing in situ methods over mining and retorting. The discussion here will be limited to those processes being tested, or soon to be tested, on either private leases or newly issued federal Research, Demonstration and Development (RD&D) leases.

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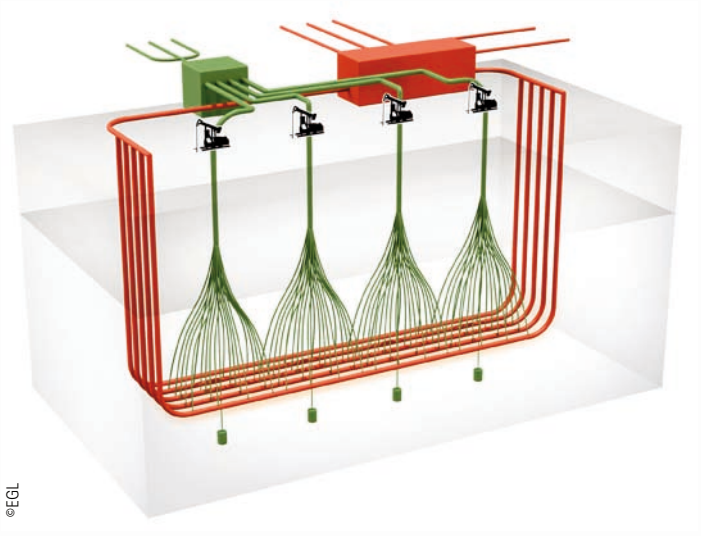
Shell's patented In situ Conversion Process (ICP) has produced high quality light crude oil at the Mahogany Research Project.

Gary Aho, using his years of experience in mining retorting, now a consultant for the Oil Shale Exploration Company (OSEC), claims that all the companies involved with extracting oil from the shale are facing similar challenges. He breaks those down this way: "Like a three legged stool, for this industry to stand on its own, three factors must be addressed, namely technology, economics, and environmental and social issues."

"The technology is still in the early research stages. We know we can get oil out of the shale, but the processes will have to deliver that oil in large quantities and be able to run all the time to be viable. As for economics, $100 oil certainly helps, but a set floor price for oil would help even more to get the investment needed to create this new industry. Finally, the environmental and social issues must be dealt with such as water, greenhouse gasses and local infrastructure."

To conserve energy, companies are working to recover heat from spent shale. Every country now producing clearly highlights their attempts to recover every bit of value from the oil shale, including using the spent shale for cement and bricks, and maximizing the production of high-value specialty chemicals that reflect the unique chemistry of shale oil.

Glenn Vawter has come out of retirement as manager of public and governmental affairs for E.G.L. Resources oil shale program. Mr. Vawter has worked most of his career in oil shale recovery and seen industry efforts come and go. "Most companies



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EGL will use proven oil field drilling and completion practices to recover oil after heating. Superheated steam is piped through a series of pipes placed below the shale bed to be retorted. Heating through lateral piping will minimize surface disturbance.

are, once again, trying to get the industry started with some profits and good environmental practices. If these efforts are successful, efficiency will improve as the industry matures," he says.

In Situ Production

Some of the in situ heating methods include using radio frequency transmitters lowered down drill holes, passing electrical current through the formation, and using hot steam or gasses pumped into the shale. Occidental was the first company to field test in situ retorting. They recovered oil from 6 retorts but because of high costs the project was closed down in 1982. Shell is the only other company to conduct field tests and is now preparing to expand the testing of their technology.

Since 1981

"Shell has been working on this technology since 1981 and has had demonstration projects in the field since 1996. The latest results clearly show our methods work. Now, the big challenge is to take this technology, scale it up and make the project environmentally responsible and socially sustainable," says Tracy Boyd, Communications and Sustainability Manager with Shell Exploration and Production Company.

Shell has been granted three 10-year RD&D leases by the BLM to prove viability of their technology in a fully integrated test. Production may be several years off, but Shell is determined to carry this on.

"It is very difficult to project what the future results may be from the small projects we have done in the past," says Tracy. "The economy of scale and using the information we have gained from those projects makes us very optimistic that oil and gas can be produced economically. We are a nation that depends heavily on liquid fuels and this is a time we direly need new sources."

Shell's patented "In situ Conversion Process" (ICP) uses vertically placed heaters that gradually heat the shale from 300 m to 600 m beneath the surface. They anticipate recovering hydrocarbons from most of the oil shale section. Heating the rock slowly to 370 °C, changes the kerogen into about 1/3 gas and 2/3 oil. These products are pumped to the surface where high quality light oil is recovered requiring fewer processing steps to produce transportation fuels.

Their Mahogany Project recovered 60% of the hydrocarbons in place. While these results are encouraging, commercial scale operations depend on results of their next phase of testing that will take several years. Commercial production is beyond that. The energy balance for such operations is currently an unknown because the research has not progressed to that stage. Using a full spectrum cost ratio, their best projection is that this process will receive 3 units of energy for each unit spent.

Shell also has an ongoing "freeze wall" experiment. In areas where ground water could be a problem, a "freeze wall" surrounding the producing area will isolate oil generation from ground water. The "freeze wall" will also protect ground water supplies from contamination.

Using CO_2

Chevron has been awarded one RD&D lease to test their "CRUSH" process. They propose to use a series of fracturing technologies to rubblize the formation horizontally to enhance the surface area of exposed kerogen.

Injection wells will be used to circulate hot carbon-dioxide-rich gases through the fractured shale formation to convert the kerogen through chemistry to a liquid and gas.

Chevron is hoping to aim at smaller portions of shale than Shell to minimize the environmental footprint, and use shale formations themselves as walls to avert seepage into groundwater.

A supergiant

E.G.L. Resources is the final company to get a RD&D lease for in situ oil recovery. Their approach is to use a closed loop to heat the oil shale with superheated steam through a series of pipes placed below the oil shale bed to be retorted. Oil and gas are produced through wells drilled vertically from the surface and "spidered" to provide a connection between the heating wells and the production system.

Both EGL and Chevron minimize surface disturbance by using lateral fracturing (Chevron) or lateral piping (EGL). EGL is still developing mitigation for subsurface water impacts. One plan is to use perimeter wells to continuously pump ground water out of the area.

If their process proves successful, they plan to expand to their 5,120 acre (21 km²) lease where they expect to recover up to 5.0 Bbo (0.8 Bm³), equivalent to a *supergiant* field.

While ExxonMobil did not receive a federal RD&D lease, their "Electrofrac" process is worth mentioning. They have been screening possible technologies for some time now. The method hydraulically fractures the oil shale and fills the fractures with an electrically conductive material, forming a heating element. This process would require fewer wells than other methods offering a reduced surface footprint. Exxon has conducted extensive laboratory research and plans are being developed for field tests on their own private lands.

While it is too early to pick a winner, Shell has clearly demonstrated that heating the shale produces good quantities of oil and gas from oil shale. Also, Shell has used their process to recover hydrocarbons from a thick vertical section. This is in contrast with other processes (Chevron and E.G. L.) that propose to laterally fracture and heat

the richer horizontal sections. The lateral processes have yet to be field tested. By only recovering hydrocarbons from the more highly organic zones, thick, less prospective sections of the shale could be bypassed or left behind, resulting in less total recovery from the oil shale.

Glenn Vawter of E.G. L. stresses that "potential reserves are very high on a per acre basis compared to many other resources. If, in fact, we ultimately exploit a thinner section of the resource, then of course overall recoveries will go down. Research, development, and demonstration will ultimately tell us how much can be economically recovered in a sustainable fashion."

Surface Methods

While many new retorting technologies are currently in the development stages, only one company, Oil Shale Exploration Company (OSEC) received a RD&D lease to test surface retorting.

OSEC plans to operate the White River oil shale mine in Utah to test their surface-based oil shale retort process developed in 1976 for treating Alberta oil sands. Over 1.5 MMb (0.24 MMm³) of shale oil were produced at the Stuart Shale Oil Project in Australia using the ATP process. OSEC plans to have a pilot operation in Utah within the next five years. They hope to eventually produce 50,000 bopd (8,000 m³ per day) in an environmentally sound and efficient manner.

The ATP processor similar to what will be used to retort oil shale in Utah.

"The advantages of using a rotating, horizontal kiln are that we can use all the shale mined because this process can handle more material sizes than vertical kilns. OSEC is still in the experimental and research stage. We recently produced oil using 300 tons (270 metric tons) of the Utah shale in the ATP pilot plant in Calgary, Canada. Testing the crude oil and spent shale is ongoing to optimize the operating parameters. Also, by retorting at higher temperatures than most in situ processes, we are able to get all fractions of the oil out of the shale and combust the residual char. Many of the lower temperature processes leave the heavier components behind," Gary Aho says.

Once the shale has been retorted in this manner, it is void of hydrocarbons and can be either used to make building materials (bricks or concrete), providing there is a market, or put back to reclaim the mining area. Either way, the process produces a small amount of water. Additional water will be needed for dust abatement and the reclaiming of mined areas.

The underground White River Mine in Utah will provide material for OSEC's retorting demonstration project.

A Long-Lasting Resource

Using past projects to take baby steps towards future production, companies are finally poised to find what has been so elusive; getting oil and gas out of oil shale that would be environmentally friendly and cost conscious.

Jeremy Boak of the Colorado Energy Research Institute at Colorado School of Mines has witnessed the progress being made. "I had heard verbal estimates of up to 3 MM bopd (500,000 m³pd) from oil company personnel who are now far more cautious. I use that figure, which is slightly larger than the 2.5 million (400,000 m³pd) by the year 2035 that DOE estimated. I do not put a date on my estimate, but expect it could be 15 to 25 years away. It took 78 years for the U.S. to reach 3 million bopd after the discovery at Titusville."

"If this level is reached, the size of the industry needed would be a significant player in the U.S. and the world petroleum picture. At this rate, the Green River resource could last several hundred years," Jeremy Boak concludes.

Eocene Library

The Green River Formation is one of the most important fossil sites in the world for understanding the Eocene. Similarly aged fossil localities in Europe and Asia are incomplete or have been disturbed while many of the Green River fossils are found intact revealing valuable information about climate, faunal changes and conditions during that period.

At the time of deposition, the area was covered by a series of large inland lakes. Over time, plants and animals were buried and fossilized at the bottoms of these lakes. Evidence from pollen grains and plant fossils such as palm trees, indicates a sub-tropical climate, similar to that of Florida. Backing up the plant indicators of climate are the presence of fossilized crocodiles which only survive where the temperatures are warm and constant.

Preservation of fossils in the Green River is amazing. The very fine-grained deposits have preserved details of life during Eocene time. Over 60 vertebrate taxa have been found including fish, reptiles, birds and mammals. Pollen grains indicate vegetation types and climate along with well preserved plant fossils such as reeds, leaves and charcoal (wood). Invertebrate fossils, primarily snails and insects, are also common. Some insect specimens are so well preserved that the compound eyes are intact. These whole specimens reveal much to researchers, giving clues as to conditions during the Eocene. The most famous and most common of those fossils are the fish found in museums around the world.

Photo: Arvid Aase, NPS

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Photo: Tom Smith

Arvid Aase, a paleontologist and museum specialist at Fossil Butte National Monument, helps visitors look for fossils and understand their importance. "The fossils indicate a much warmer and wetter climate, quite different from the high, cold desert of southwest Wyoming."

Wonderfully preserved insect, plant and fish fossils have made the Green River shale world famous.

Photo: Arvid Aase, NPS

Finely bedded Green River shale is the objective for fossil hunters and oil companies.