years of lab work, but the company dug in. "Shell continued doing research even in the 1980s when most everyone else quit," says Glenn Vawter admiringly. Vawter, a veteran of Exxon's failed oil shale operation, is now an executive with an oil shale startup, EGL Resources. In 1998—when the price for West Texas crude crashed to less than $15 a barrel—Shell spent $799 million on R&D; by comparison, the larger Exxon Mobil spent $549 million. In 2006, Shell spent $855 million on R&D to Exxon's $733 million. Both Vinegar and Shell vice president for unconventional production John Barry confirm that oil shale is now the biggest piece of the company's R&D budget, though neither will specify exactly how much has been spent. One source briefed by Shell officials puts the total oil shale R&D investment at north of $200 million.

Shell has long been known for its science. It invented the first semi-submersible offshore drilling rig and pioneered the use of steam flooding to maximize oil well production; it's also the industry leader in natural-gas-to-liquids (GTL) technology. Much of its research originates at its Bellaire Research Center in Houston, where Vinegar has spent most of his career. The lab's most famous alumnus is the late M. King Hubbert, of Hubbert's Peak fame. Hubbert was the first geologist to understand the mechanics of oilfield depletion and the first to make a reasonably accurate assessment of recoverable oil reserves—initially for the U.S. and later for the world. The founding father of peak-oil theory, Hubbert predicted that U.S. production of conventional oil would peak around 1970 (he was right) and that global oil production would taper off after 2000 (he was wrong, though by how much is the topic of heated debate).

Neither Vinegar nor Barry wants to get drawn into a discussion of peak-oil theory. They simply state that the rapid growth in worldwide oil demand necessitates the development of unconventional oils. (Shell has also invested in biofuels and solar power.) That said, it's no coincidence the oil company Hubbert once called home is the one now making the biggest bet on unconventional oil—not only oil shale but GTL and Canadian tar sands too. Jim Spehar, a former Colorado community-relations consultant for Shell, remembers company scientists and executives talking at length about peak oil—and about oil shale as a potential "bridge" between conventional oil and renewable energy—when he worked for Shell in the late 1990s. "They definitely believed that the conventional stuff being pumped out of the ground was a declining resource," Spehar says.

VINEGAR AND THE SHELL TEAM OF CHEMists, engineers, and physicists eventually figured out why the oil they collected early in that 1981 field test was so light and clean and the later samples so dark and dirty. They found that a slower, lower-temperature process—650 degrees Fahrenheit, vs. the 1,000 degrees required in the retorting process—allows more of the hydrogen molecules that are liberated from the kerogen during heating to react with carbon compounds and form a better oil. This was a crucial discovery, because one of the hallmarks of a light oil—the most valuable kind because it costs less to refine—is its elevated hydrogen content.

Best of all, Shell was able to replicate the lab results in several

SCALING UP The first field test (inset), in 1981, squeezed out a few cups of good oil and a lot of junk; 24 years later and on a different site, Shell was able to produce 1,700 barrels of high-quality oil.