Refracturing may not be all it’s cracked up to be

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Refracturing may not be all it's cracked up to be

Restimulating oil and gas wells that have been fracked will be worthwhile in some cases, but not all.

Hydrofracturing, or fracking, has been extremely effective in unlocking natural gas and oil from shale and other low-permeability rock formations in the US. So it might seem intuitive that refracturing the tens of thousands of existing fracked wells could unleash a second boom at comparatively low cost and without the environmental effects of drilling new wells. Experts say it's not so simple.

A recent analysis by Richard Middleton and colleagues at Los Alamos National Laboratory (LANL) of 20 000 shale gas wells in Texas concluded that refracturing previously fracked horizontal wells "has profound implications in the potential revitalization of the hundreds of thousands of shale gas wells across the United States." Refracturing the wells could turn them into higher-producing assets, said the study, published in the online journal *Applied Energy* in May.

The combination of horizontally drilled wells and fracking with large volumes of fluid has resulted in a dramatic increase in US gas and oil production since the turn of the century (see the articles by Donald Turcotte, Eldridge Moores, and John Rundle, PHYSICS TODAY, August 2014, page 34, and by Michael Marder, Tadeusz Patzek, and Scott Tinker, PHYSICS TODAY, July 2016, page 46). Separately, many conventional vertical oil and gas wells are fracked at lower pressures and with smaller volumes of water to stimulate continued production. Most horizontal wells run 1 km or more through the shale reservoir. Vertical wells, by comparison, penetrate the reservoir for a far shorter distance.

According to the LANL analysis, on average just 13% of the gas from any given US shale is recovered. The potential for restimulating existing wells is therefore huge. What's more, notes Hari Viswanathan, a coauthor of the LANL paper, drillers have learned a lot in recent years about controlling the fracking process and how to create well-connected fracture networks.

DAVID R. TRIBBLE VIA WIKIMEDIA (CC BY-SA 3.0)

A SHALE GAS hydraulic fracturing rig in Texas's Barnett Shale formation.

Other experts are less enthusiastic. Of the tens of thousands of horizontal wells, only a small number—600, by one estimate—have been refractured to date. Refracturing is economically justifiable only for a subset of wells, says Frank Male, a postdoc at the University of Texas at Austin's Bureau of Economic Geology. "Since around 2012, [drillers] have reached the point of having a relatively stable fracture formula, and you won't get any improvement" from

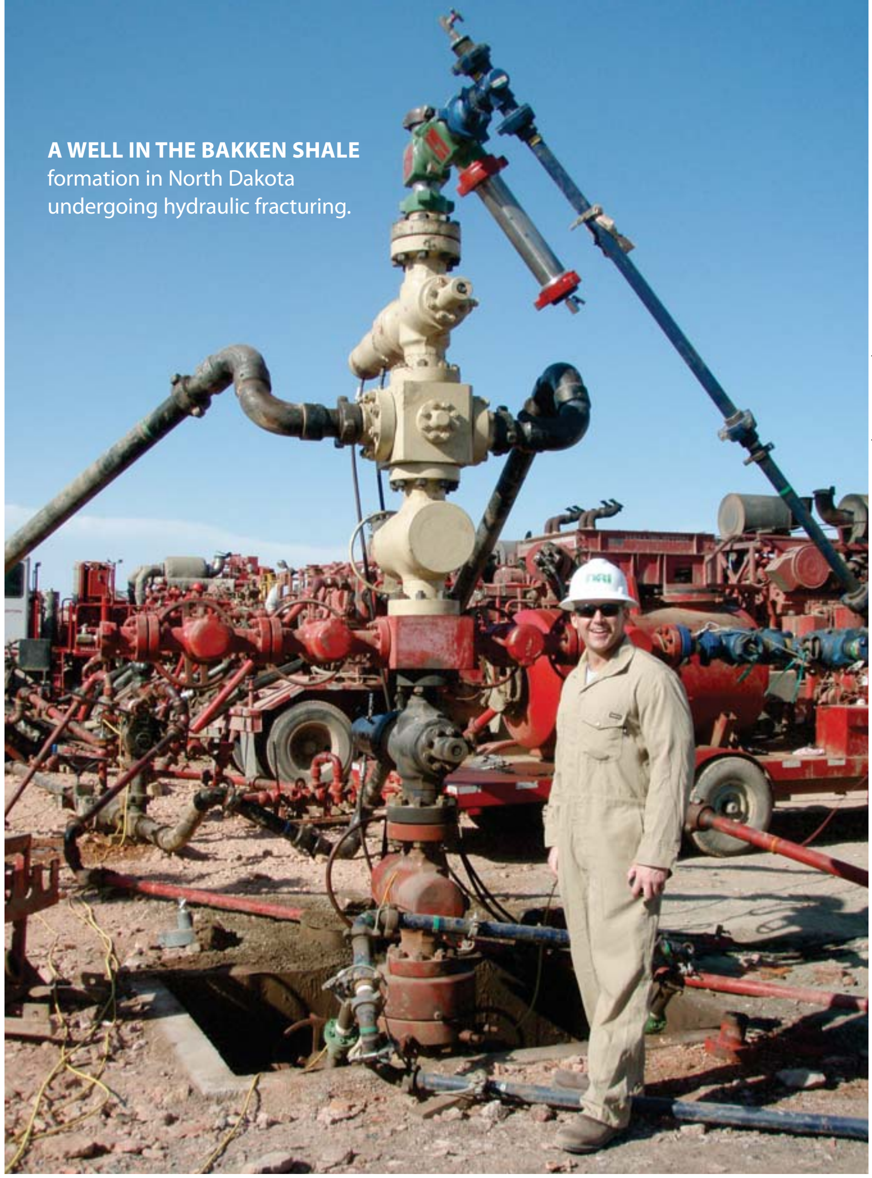
refracturing, says Male, who estimates a total of 129 000 horizontal wells have been drilled in the US since 2001.

Over the years, fracking technology has improved, mainly through practice, so that the distance between individual fracking operations along the horizontal leg of wells has narrowed to around 6 m, down from 30 m in 2004, says Male. That has vastly improved recovery of hydrocarbons; production rates doubled in 2007–11 alone.

The Los Alamos study examined wells drilled over 23 years in the Barnett Shale, a major US oil- and gas-bearing shale formation in the Fort Worth Basin of Texas. The analysis began with what the researchers said were the first "technically successful" wells in 1998. Poorly performing wells that were first fracked before 1998 and refractured in 2000–04 performed better than those first fracked in 1998–2006, according to the LANL analysis.

But Male notes that LANL's data source, the Texas Railroad Commission, which regulates oil and gas drilling in the state, doesn't differentiate in publicly released data between refractures of existing horizontal wells and the conversion of vertical wells to horizontal ones, followed by the fracking of their horizontal sections. Male says that conversion—essentially the creation of new wells, not refracking—was actually occurring most frequently throughout the period in the Barnett Shale.

Viswanathan agrees that wells fracked in the past five years aren't good candidates for refracturing with water. But he says that fracking with nonaqueous fluids such as supercritical carbon dioxide or other inert gases could make even recently drilled wells good candidates for refracturing.



A WELL IN THE BAKKEN SHALE formation in North Dakota undergoing hydraulic fracturing.

JOSHUA DOUBEK VIA WIKIMEDIA (CC BY-SA 3.0)

Refrack or not?

It's far more common to refracture vertical wells than horizontal wells; Tim Leshchyshyn, president of FracKnowledge in Calgary, Alberta, Canada, estimates that the process has been performed 100 000 times, and says some vertical wells are refractured every 3 to 4 years during their 20-year lifetime. For horizontal wells, though, only about half of refractures produce enough additional gas or oil to recover the cost of the job, he says. "Refracturing is a great way to recycle [horizontal] wells and squeeze another 25% to 400% more production out of them. But you can't just do it anywhere," he says. "You have to know you are doing it to solve some problem, and that fracturing it again will solve that problem." One good reason to refracture could be a deposit buildup in the fracture network caused by the precipitation of heavy crude-oil components, says Leshchyshyn.

A 2015 study by the research firm IHS found that just 600 horizontal wells in the US had been refractured. It predicted that as many as 11% of US horizontal wells may be refractured by 2020, but it found that the refracking that has been done had mixed results. On average, the initial production rate of refractured wells was equivalent to 98% of the wells' initial production rate after the original fracking. Refractured wells had slightly better 12-month production decline rates compared with the 12-month declines that followed the original fracking.

The IHS report said the average increase in performance was heavily skewed by some of the earliest horizontal fracked wells, mainly in the Bakken Shale of North Dakota and Montana, which had been particularly poor performers. Most of the refractures that occurred in other formations, such as the Marcellus Shale formation in the Appalachians, were less productive.

Looking for a quick payback, drillers tend to focus on production from the initial 12 months after fracking, the LANL report stated. Left alone, however, a fracked well will typically produce 75% of its 10-year output in years 2–10.

The IHS report said that due to technical challenges, uncertainties, and costs, companies with a portfolio of new well prospects will likely drill them first and wait for further technological advances before refracturing their older producing wells.

Industry consultant George King says that recovery rates in gas shales such as the Marcellus are very different from those in oil-rich shale basins such as the

Bakken. He notes that some oil-shale wells could be stimulated with enhanced oil-recovery technology, including a technique known as “huff and puff,” in which CO_2 or steam is injected into a formation and allowed to sit prior to the well’s being put back into production.

Explosive growth

Although hydraulic fracturing has been in use for more than 60 years, it has only been a significant source of US oil production since the turn of the century. As of 2015, the Energy Information Administration (EIA) estimated that hydrofractured wells, both horizontal and vertical, accounted for half of US crude-oil production. Growth has been explosive: In 2000 approximately 23 000 fracked oil wells produced a combined total of 102 000 barrels per day—less than 2% of the US total. By 2015 the number of fracked oil wells in service grew to around 300 000, which produced 4.9 million barrels per day, according to the EIA. So-called tight oil production from shale and sandstone is expected to increase through around 2030, when two of the major formations begin to decline.

As for natural gas, the 37 billion cubic feet per day produced by some 300 000 fracked horizontal and vertical gas wells accounted for two-thirds of total US production in 2015, according to the EIA. That is up an order of magnitude from the 3.6 billion cubic feet per day, or 7% of US output, from 26 000 fracked wells in 2000.

In a 2016 report, the EIA said just three other countries—Argentina, Canada, and China—had commercial shale gas and tight oil production. But technological improvements are expected to encourage the development of shale resources in other countries, primarily Mexico and Algeria. Forty-two other countries have technically recoverable but so far uneconomic oil and gas shales, the EIA said.

Alternative frack fluids

Due to their low permeability, shales and sandstones must be fractured to provide paths for the gas and oil to flow from the rock to the well bore. Water, with chemical additives, is almost always the fracturing fluid, coupled with sand or ceramic material that is forced into the fractures to hold them open. A typical fracked well uses 7.5 million to 15 million liters; anywhere between 15% and 80% of the liquid flows back to the surface in the early stages of gas production, depending on geology and other factors. But Male cites one study of shale wells in the Permian Basin of Texas showing that some wells yielded more water than was injected.

One advantage of using a nonaqueous fracking fluid such as supercritical CO_2 would be to reduce the need to dispose of the contaminated water, which can contain acids, gelling agents, bactericides, corrosion inhibitors, and friction reducers, in addition to radionuclides and metals from the shale. Another plus is that unlike water, CO_2 is miscible with oil and gas, and it won’t block hydrocarbons from flowing to the well. Third, Viswanathan says that CO_2 creates more-productive branched fractures in the rock, while water typically produces simple planar fractures.

Disadvantages include the need to separate the CO_2 from the natural gas, and capturing and pressurizing the CO_2 for reuse. Nearly all of the CO_2 that is used for industrial applications and for enhanced oil recovery in the US today is supplied from naturally occurring underground formations located mainly in the Four Corners region, where Arizona, Colorado, New Mexico, and Utah meet. Liquefied natural gas and mixtures of CO_2 and nitrogen are other candidate alternative fluids, says Andres Clarens, associate professor of civil engineering at the University of Virginia.

Leshchyshyn participated in fracks using supercritical CO_2 some 20 years ago. “It’s a great technology,” he says. Limited availability of CO_2 and the expense of getting it to the well site may make it economically unattractive now, but Leshchyshyn foresees that possible government bans on the use of clean water for fracking could change the equation.

A potential future environmental benefit from using supercritical CO_2 would be the permanent sequestration of the greenhouse gas underground. Compared to water, the superior fracturing obtained with CO_2 will increase the holding capacity of the well, says Viswanathan. Moreover, CO_2 injection can occur at the same time the oil or gas is being extracted. Depleted shale formations would be able to hold as much as five times the amount of CO_2 compared with the methane they once held, says Clarens, who has examined the storage capacities of fractured wells.

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