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Unlocking the Earth

A Short History of Hydraulic Fracturing

MICHAEL QUENTIN MORTON

The recent shale gas boom is a reminder that the effective use of hydraulic fracturing in shale formations is a relatively new phenomenon. However, this 'fracking' (also called 'fracing' or 'fraccing' in the technical literature) has been around for longer than many people realise, and the use of unconventional techniques to extract oil and gas from the ground has developed over more than 150 years.

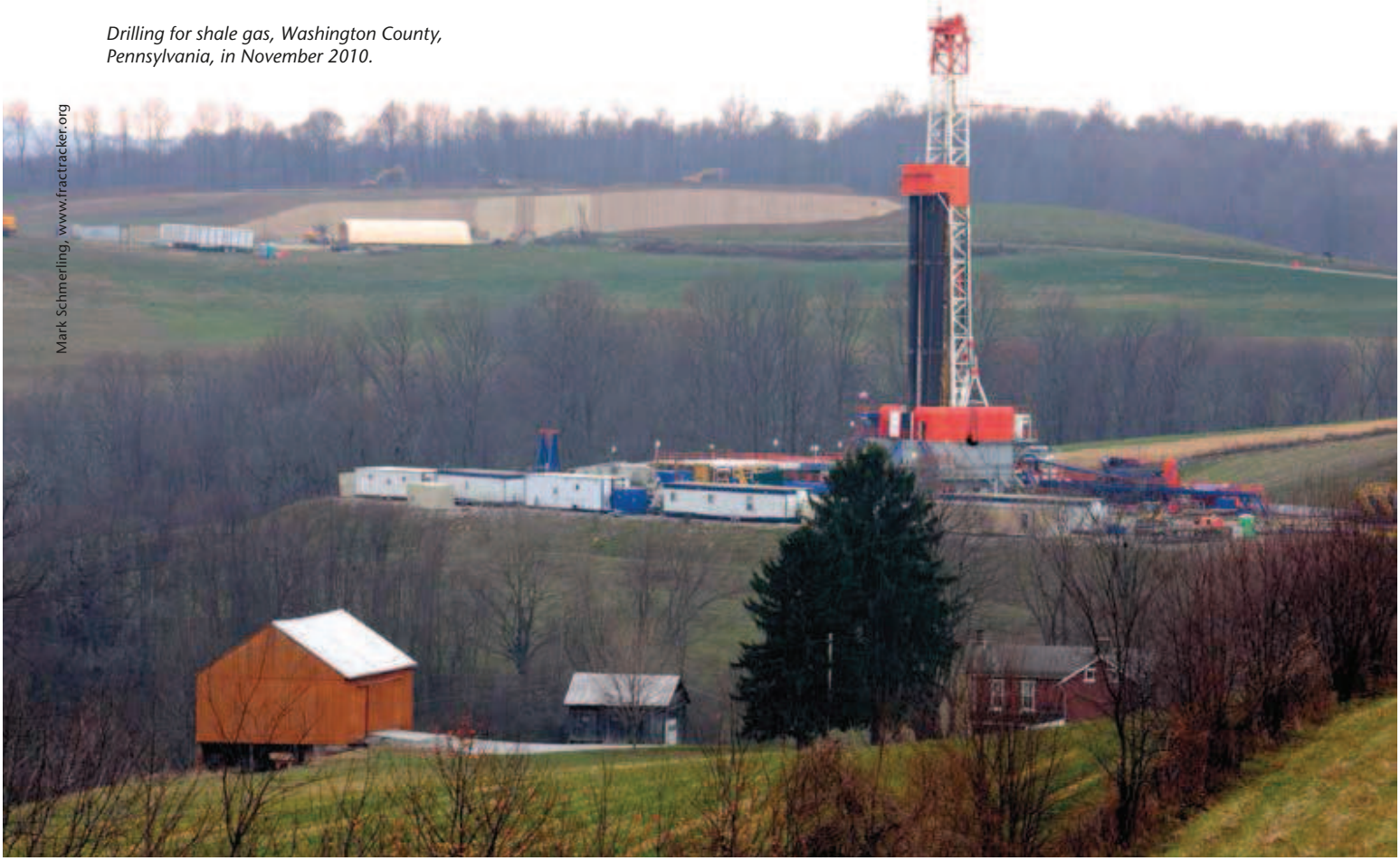
Fracking has come a long way since 1857 when Preston Barmore lowered gunpowder into a well at Canadaway Creek, NY, and dropped a red-hot iron down a tube, resulting in an explosion that fractured the rock and increased the flow of gas from the well.

Hydraulic fracturing, as its name suggests, involves pumping water and sand at high pressure to fracture subterranean rocks. This might appear far removed from the mid-nineteenth century practice of 'shooting' a well, which used explosives instead of water, but the basic principle is the same. Drillers freed-up clogged or non-productive wells by creating underground explosions to loosen rock or debris. The effect was often the reverse of modern fracking: a column of earth, water and oil would shoot out of the well head, a spectacle for onlookers but hardly a reliable industrial process.

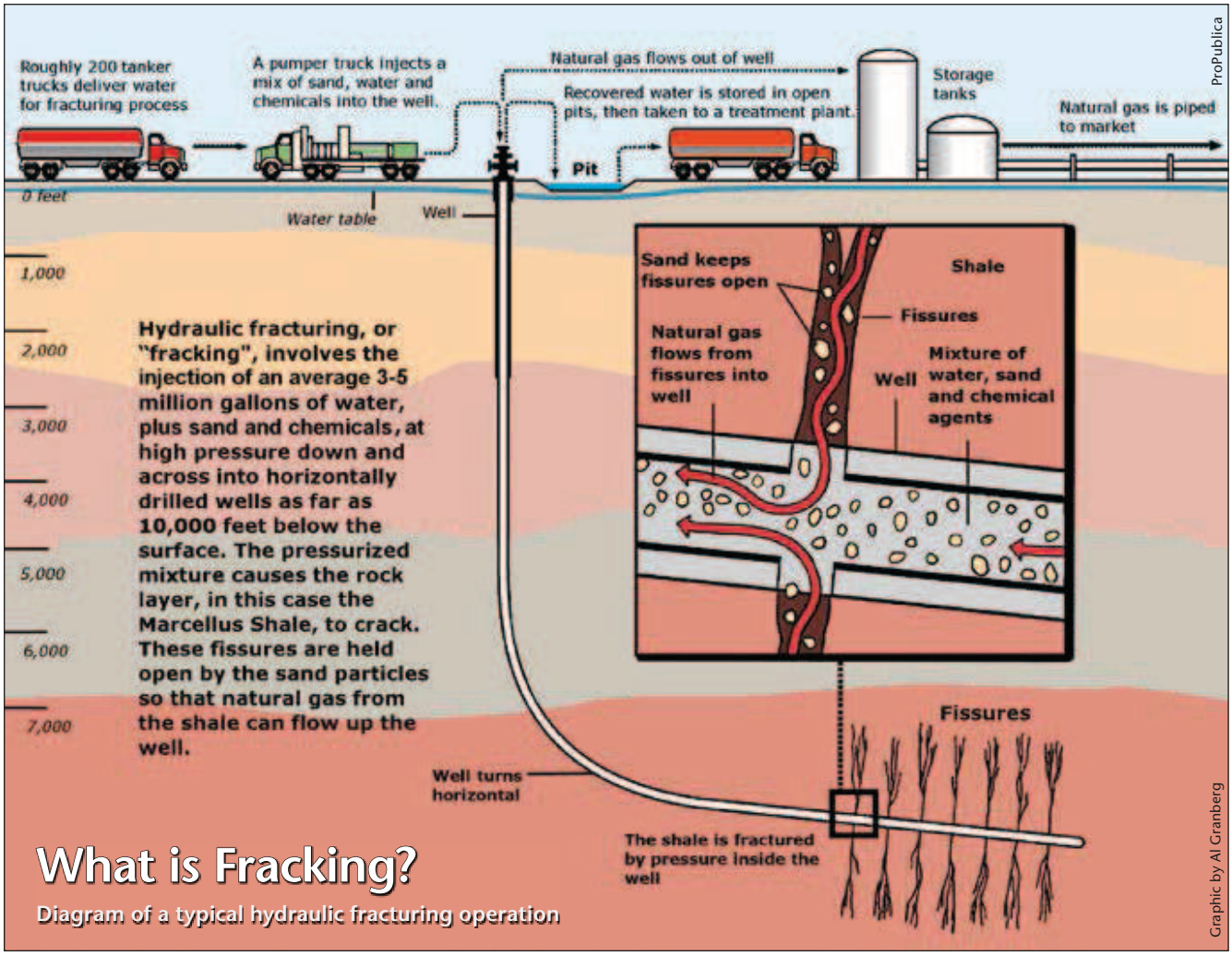
Courtesy of The Drake Well Museum, Pennsylvania Historical and Museum Commission

In 1865, Col. Edward Roberts and his brother developed a technique known as 'super-incumbent fluid-tamping', in which water dampened the explosion, preventing any debris blowing back up the hole and amplifying its effects. They also developed a nitro-glycerine 'torpedo', replacing the black powder and gunpowder that had previously been used. Their legacy lives on with the Tallini and Otto Cupler Torpedo Company, which still shoots wells with

Drilling for shale gas, Washington County, Pennsylvania, in November 2010.



Mark Schmerling, www.fractracker.org



modern explosives and rigorous safety procedures.

It was left to others to develop techniques to crack the rock: in the 1930s, experiments were conducted using acid instead of explosive, a technique known as 'pressure parting' and, in April 1939, patents were taken out for a device in which projectiles were shot through a casing into the rock formation.

The Advent of Fracking

In the 1940s, Floyd Farris of Stanolind Oil proposed that fracturing a rock formation through hydraulic pressure might increase well productivity. This was followed in 1947 by the first application of the 'Hydrafrac' process at the No.1 Klepper well in the Hugoton Field, Kansas. One thousand gallons of naphthenic acid and palm oil (napalm) were combined with gasoline and sand to stimulate the flow of natural gas from a limestone formation.

In 1949, Halliburton Oil Well Cementing Company obtained an exclusive licence (subsequently extended to other qualified companies) for the hydraulic fracturing process. In the first year of operations, 332 oil wells were treated with crude oil or a combination of crude oil, gasoline and sand. The wells on average increased production by 75%. From 1953, water was also used as a fracturing fluid, and various additives were tried to improve its performance. By 1968, fracking was being used in oil and gas wells across the United States, but its application was limited to the less difficult geological formations.

The Fracking Breakthrough

Fracking was transformed when it was combined with horizontal drilling and other new technologies, such as 3D seismic imaging. Horizontal drilling wells extended the range of fracturing sideways along a rock formation rather than contacting it vertically. Millions of gallons of water mixed with sand and chemicals were then injected at high pressure into the well to fracture the

The Barmore well in 1858.

Courtesy of the Darwin Barker Historical Museum

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rock. This mixture (or 'proppant') filled the fissures and propped them open, allowing trapped oil and gas to flow out.

Shale rock presented a particular challenge because of the difficulty in accessing the hydrocarbons in these tight formations. In the mid-1970s, the US Department of Energy (DOE) and the Gas Research Institute (GRI), in partnership with private operators, began developing techniques to produce natural gas from shale. These included the use of horizontal wells, multi-stage fracturing, and 'slick' water fracturing (*GEO ExPro* Vol. 9, No. 2).

Between 1981 and 1998 a Texas company, Mitchell Energy and Development, experimented with these techniques in testing the Barnett Shale formation. Commercial success came when the company combined them with slick water, a low viscous mixture that could be rapidly pumped down a well to deliver a much higher pressure to the rock than before. A merger between Mitchell Energy and Devon Energy in 2002 brought a rapid increase in the use of fracking with horizontal drilling. With other companies involved, fracking spread to shale exploration in Texas, Oklahoma, Arkansas, Louisiana, Pennsylvania, West Virginia and the Rockies.

American Oil and Gas History Society

The first commercial hydraulic fracking site at Duncan, Oklahoma, in 1949.

Fracking 'Quakes

As public awareness of fracking has grown, so have concerns about the process, especially the large volume of water used, the resulting wastewater, air pollution and the consequences of injecting chemicals deep underground. Opponents point to the possible contamination of aquifers by chemicals associated with fracking or by the escape of methane gas. According to geologists, it is unlikely that the gas will rise far enough to reach the shallow aquifers that supply drinking water, although some researchers disagree. It appears that, at production sites, fracking causes lower leakages of methane than had been feared. In a number of cases, landowners and farmers have claimed that leaks from holding ponds, spills and underground ruptures have polluted their water.

A hydraulic fracturing operation at a Marcellus Shale well, Pennsylvania.

US Geological Survey

Microearthquakes (less than magnitude 3 on the Richter Scale) are an integral part of fracking. They carry a very low risk of destructive effects – virtually all observed microseismic events associated with fracking are of a magnitude -0.5, well below levels that are noticeable to the public. Small earthquakes in south Texas have been linked to increased extraction of oil and brackish water in the shale boom, but not directly to the fracking process. Low-level seismic events between 2009 and 2011 in remote areas of the Horn River Basin, British Columbia, were caused by fluid injection during hydraulic fracturing in proximity to pre-existing faults, but only one of these events could be 'felt' at the earth's surface and no damage or injury was caused.

Most earth tremors attributed to fracking are associated with the injection of wastewater into wells deep underground. This can change the fluid balances in rocks and the stresses in the Earth's crust near a fault. Generally, these so-called 'disposal wells' carry a small risk of induced seismicity and, in

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relation to their large number, there have been few recorded seismic events. However, a 5.7-magnitude earthquake in Oklahoma in 2011 has been linked to the disposal of wastewater from oil production. It appears that some areas in the mid-western United States are prone to a process called 'dynamic triggering' whereby distant earthquakes might trigger minor earthquakes along faults which have been 'critically loaded' by disposal wells. If strategies are devised to minimise the impact of these wells on underground fluid balances, then the risk of induced seismicity will be reduced.

The Hamster's Wheel

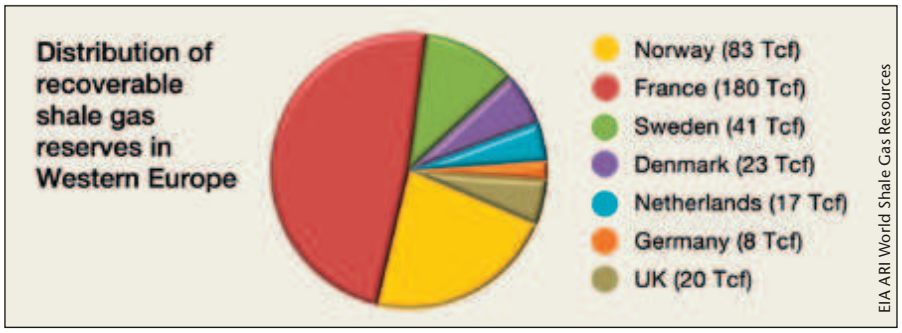
The International Energy Agency (IEA) estimates that, over the next five years, the US will account for a third of new oil supplies. The growth in US production is largely attributable to a steep rise in the recovery of shale oil, in which fracking has played a major part, unlocking major shale rock formations such as the Bakken in North Dakota and Montana.

The tables are turning. The US is likely to change from the world's leading importer of oil to a net exporter and, according to the IEA, will be self-sufficient in its energy needs by 2035. It has also led to a refocusing of US foreign policy, away from an historical reliance on the oil-rich countries of the Middle East.

The natural gas boom initiated by fracking has had a number of consequences (*GEO ExPro*, Vol. 10, No. 3). In the United States, with low prices resulting from the development of unconventional gas, producers are currently active in preserving leases for future development. Today's story is more about fracking for liquids – natural gas liquids (aka condensate) and oil. Commodity prices and economics are driving relentless activity in the Eagle Ford Basin in south Texas, the Permian Basin, the Williston Basin in North Dakota, and the Utica Shale in western Pennsylvania and eastern Ohio. Like a hamster on a wheel, the producer has to keep production numbers up, or even rising, in order to satisfy investors.

Fracking in Europe

Europe's reserves of 639 Tcf compare favourably with America's 862 Tcf, but there are other factors to consider. European geology tends to be more complicated, with the shale buried deeper underground and therefore more expensive to extract. According to Deutsche Bank, a well in Europe might cost as much as three-and-a-half times more than one in the US.



The American gas industry is less restricted than in Europe, with hydraulic fracturing being exempted from the Safe Drinking Water Act. This contrasts with France, where there is a moratorium on fracking while an assessment of the risks is carried out. But some countries have forged ahead: in Poland, for example, exploration licences have been issued to 20 firms, test wells have been drilled, and commercial production is likely to commence in 2014.

In the United Kingdom, until the occurrence of two small earthquakes (3.2 and 2.4) in Lancashire in 2011, fracking was not widely known. In fact, the process has been going on since the 1970s, with 200 wells fracked onshore and even more in the North Sea. Various experiments have been tried: the Lidsey oil well, for example, was fracked in September 1991 using as the fracturing agent microbial acid, otherwise known as Marmite, a yeast and vegetable extract. In theory, Marmite (and molasses) would be food for special bacteria, which would excrete acid to dissolve the carbonate rock. Unfortunately, it also fed the indigenous bacteria to produce hydrogen sulphide gas. The well was also fractured with a typical sand frack before the Marmite treatment, and is still producing today.

Unanswered Questions

Although the global potential of shale gas is vast, it is uncertain how much can be produced. And, although shale gas is cleaner to burn than conventional fossil fuels, its overall impact on global climate change is difficult to predict. Environmental concerns persist: in China, drilling for oil has begun in the earthquake-prone Sichuan region; in South Africa, the government has lifted a moratorium to allow fracking in the Karoo region, raising fears of damage to its ecosystem. Whatever fracking's real benefits, one thing is certain: the arguments over its future risks and impact are set to rumble on.

Acknowledgements:
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West Sussex, England, 1991: the fracking fluid in the tanks is pumped into the well using Marmite in the fracturing process.

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