

## **Add Quakes to Rumbblings Over Coal Seam Gas Rush**

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YOUNGSTOWN, Ohio — Until this year, this Rust Belt city and surrounding Mahoning County had been about as dead, seismically, as a place can be, without even a hint of an earthquake since Scots-Irish settlers arrived in the 18th century.



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But on March 17, two minor quakes briefly shook the city. And in the following eight months there have been seven more — like the first two, too weak to cause damage or even be felt by many people, but strong enough to rattle some nerves.

“It felt like someone was kicking in the front door. It scared the stuffing out of me,” said Steve Moritz, a cook who lives on the city’s west side, describing the seventh quake, which occurred in late September. It was the strongest one, with a magnitude of 2.7.

Nine quakes in eight months in a seismically inactive area is unusual. But Ohio seismologists found another surprise when they plotted the quakes’ epicenters: most coincided with the location of a 9,000-foot well in an industrial lot along the Mahoning River, just down the hill from Mr. Moritz’s neighborhood and two miles from downtown Youngstown.

At the well, a local company has been disposing of brine and other liquids from natural gas wells across the border in Pennsylvania — millions of gallons of waste from the process called hydraulic fracturing that is used to unlock the gas from shale rock.

The location and timing of the quakes led to suspicions that the disposal well was responsible for Youngstown’s seismic awakening. As the wastewater was injected into the well under pressure, the thinking went, some of it might have migrated into deeper rock formations, unclamping ancient faults and allowing the rock to slip.

As the United States undergoes a boom in the production of gas from shale, hydraulic fracturing, or fracking, has come under fire from environmentalists and others for its potential to pollute the air and contaminate drinking water. But the events in Youngstown — and a string of other, mostly small tremors in Arkansas, Oklahoma, Texas, British Columbia and other shale-gas-producing areas — raise the disquieting notion that the technique could lead, directly or indirectly, to a damaging

earthquake.

Scientists say the likelihood of that link is extremely remote, that thousands of fracking and disposal wells operate nationwide without causing earthquakes, and that the relatively shallow depths of these wells mean that any earthquakes that are triggered would be minor. “But still, you don’t want it to happen,” said Mark Zoback, a geophysicist at Stanford University.

Others point out that among the thousands of small earthquakes in central Arkansas since last year that were thought to be linked to disposal wells was one of magnitude 4.7, and that a disposal well at the Rocky Mountain Arsenal in Colorado — for wastewater from weapons production, not gas drilling — was tied to numerous quakes in the 1960s, including several of magnitude 5.0 or higher that caused minor damage in Denver and other cities. Deeper geothermal wells have caused damaging quakes as well.

“It’s true that you can’t have an earthquake larger than a given fault can provide,” said Serge Shapiro, a professor at the Free University of Berlin who has studied what scientists refer to as induced seismicity. “But an earthquake even of magnitude 4 in a populated area can be an unpleasant thing.”

Officials with D & L Energy, the Youngstown company that has been disposing of the waste, and with the Ohio government say there is no proof of a link between the disposal well and the earthquakes. “Right now we can’t definitively say yes or no,” said Tom Tugend, deputy chief of the gas and oil division of the Ohio Department of Natural Resources. But the state has asked the company to plug the bottom 250 feet of the well with cement as a precaution, to ensure that it is sealed from the deeper rock where the earthquakes are thought to have occurred.

State officials are also working with researchers from the Lamont-Doherty Earth Observatory, a part of Columbia University, who have installed four temporary seismometers within several miles of the well. If more earthquakes occur, the instruments will help determine location and depth more precisely. “It should help us make the case one way or another — is this related or not,” said John Armbruster, a Lamont seismologist.

C. Jeffrey Eshelman, a spokesman for the Independent Petroleum Association of America, said that as far as the industry was concerned, “it has been impossible to determine whether hydraulic fracturing has anything to do with” the quakes like those in Ohio.

“But it’s in our best interest to understand what’s going on,” he said. “Although they are minor incidents, they are still something to be taken seriously.”

Scientists say that although it is known that wells — and reservoirs and quarries, among other things — can induce earthquakes, it can be difficult to prove a connection because there is not enough data. So specific cases often become a subject of debate.

“Scientific research needs to be done to understand the data on fluid injections and volumes,” said William Leith, senior science adviser for earthquake and geologic hazards at the United States Geological Survey, which has re-established a project to study induced seismicity in response to the string of suspicious quakes in shale-gas areas.

In Arkansas, the State Oil and Gas Commission was concerned enough about a possible link between disposal wells and earthquakes that in July it ordered that one well be shut down, and it placed a moratorium on new ones in an 1,100-square-mile area. Three other disposal wells closed voluntarily.

While small earthquakes are still occurring in the area, their frequency has declined substantially.

In Oklahoma, a state seismologist concluded that there was a “possibility” that a series of small quakes in January about 50 miles south of Oklahoma City were induced by a nearby fracking operation. “The reason I can’t make any real conclusive statements is just because of the limitations of the data,” the seismologist, Austin A. Holland, said.

In northwestern England, however, an independent report commissioned by a drilling company, Cuadrilla Resources, concluded that two quakes of magnitude 1.5 and 2.3 near the city of Blackpool last spring were related to a fracking well. The report suggested several ways to avoid further quakes, including monitoring and limiting the pressures and volumes of fluid used.

Fracking is known to cause very slight tremors — far weaker than even the Youngstown quakes — when the fluid is injected into the shale under high pressure. Drilling companies often send sensitive instruments called geophones into the drill holes to analyze these tiny tremors because they indicate whether the rock is fracturing as expected.

But the larger earthquakes near Blackpool were thought to be caused the same way that quakes could be set off from disposal wells — by migration of the fluid into rock formations below the shale. Seismologists say that these deeper, older rocks, collectively referred to as the “basement,” are littered with faults that, although under stress, have reached equilibrium over hundreds of millions of years.

“There are plenty of faults,” said Leonardo Seeber, a seismologist with the Lamont-Doherty Earth Observatory. “Conservatively, one should assume that no matter where you drill, the basement is going to have faults that could rupture.”

Drilling and disposal companies do not usually know that those faults exist, however. Seismic surveys are costly, and states do not require them for oil or gas wells (although larger companies routinely conduct seismic tests as part of exploration). Regulations for disposal wells are concerned about protecting aquifers, not about seismic risk. The federal Environmental Protection Agency, which regulates oil- and gas-related disposal wells unless its cedes its authority to the states, has no seismic requirements for its disposal wells, an agency spokeswoman said.

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