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Oklahoma used to average fewer than two earthquakes of magnitude 3 or greater a year. In 2015, it had more than 900. What on earth is going on there?

Gerik Lovett was in class in Lexington, Oklahoma, when the then middle-schooler experienced his first earthquake. "I heard the growl and I knew: There's gonna be an earthquake!" Gerik recalls. "The school building shook; it shifted and moved back, really quickly."

That was six years ago. At about the same time, people in other parts of the state began feeling similar jolts.

Scientists say the state's quakes are likely due to human activity--the result of digging wells to store wastewater produced by oil and gas drilling. Earlier this year, industry regulators issued new standards for such wells. Still, Oklahomans have had to adjust to a new normal: knowing that the earth under their feet could shake at any time.

**A NEW QUAKE COUNTRY**

For decades, Oklahoma averaged fewer than two earthquakes of magnitude 3 or greater each year. (On the scale geologists use to measure tremor strength, anything 3 or higher is big enough for people to feel.) But in 2009, the number of such quakes suddenly jumped to 20; by 2015, it had skyrocketed to 907.

Then, this past September, Pawnee, Oklahoma, was hit by the biggest quake in the state's history: a 5.8-magnitude tremor that was felt not only in Oklahoma, but in five neighboring states as well.

None of these quakes has been deadly. But some have caused severe damage as well as injuries. "A lot of rural houses ... are seeing extensive damage," said Pawnee County Sheriff Mike Waters after the September quake.

And according to the U.S. Geological Survey (USGS), a federal scientific agency, the chances for a destructive earthquake in north-central Oklahoma are now as great as in the most earthquake-prone areas of California, the state best known for seismic activity. (See map, p. 21.)

**WHAT'S CAUSING IT?**

Scientists have concluded that Oklahoma's huge increase in seismic activity was caused by the way oil and gas companies were disposing of wastewater produced by drilling.

Oklahoma has been oil country since 1859, when a man drilling for salt water to make salt went very deep--and struck oil instead. Today, large-scale deep drilling for oil and gas brings up billions of barrels of salt-water waste. (One barrel equals 42 gallons.)

"It's very salty water and also has some bad chemicals in it, so you can't dispose of it very easily," says Jeremy L. Boak, director of the Oklahoma Geological Survey. "So the best thing to do is to put it back into a deep geologic formation."

That's why oil and gas companies dig immense underground disposal wells and pump the wastewater into them. In recent years, companies in Oklahoma began putting those disposal wells into or below the Arbuckle formation. The Arbuckle is a layer of rock 7,000 feet below the surface in Oklahoma.

But, says Boak, we put too much there. All that water began exerting tremendous pressure on the layer of rock several miles below the Arbuckle--and on faults (breaks in Earth's crust) that already exist there. The added pressure forced those faults apart, creating the surface tremors known as earthquakes.

"We exceeded the ability of this one formation to take it," Boak explains. "It became pressurized to the point where it was triggering earthquakes deep below it."

**ASHAKYFUTURE**

The Oklahoma Corporation Commission regulates the state's oil and gas industries. It responded to Oklahomans' concerns about the increased seismic activity by issuing new regulations in early 2016.

Wastewater wells are now being made shallower, says Rhoda McLean, an oil and gas attorney in Edmond, Oklahoma. Disposal wells must now be located above the Arbuckle. Also, there must be fewer such wells, and they have to be placed farther apart.

So far, the new measures seem to be having a positive effect: The number and frequency of quakes are down. However, pressure from existing disposal wells can take a long time to build up enough to set off a quake, so the risk of earthquakes remains.

"We can't rule out the possibility of a magnitude-6 earthquake or even something larger," says Boak.

The potential for such an event is unsettling for many Oklahomans. Some are worried that "a big one" could strike in a populous urban area, like the capital, Oklahoma City. There, the damage would be far greater than with a similar event in a rural area.

Others take the quakes in stride. Compared with deadly tornadoes, which are also common in the state, Gerik says, occasional tremors are easy to deal with. "It's just every once in a while, the ground shakes. We're like, 'Hope it didn't break anything. Let's watch some TV.'" ?

\* Induced earthquakes are tremors caused by human activity.

Oklahoma Earthquakes

Magnitude 3.0

and Greater

Number of Earthquakes per Year

1978 to 2008 <2/yr (avg)

2009 20

2010 41

2011 67

2012 35

2013 110

2014 579

2015 907

2016 \* 537

\* As of 10/17/16

SOURCE: Oklahoma Geological Survey

Note: Table made from bar graph.