Supercharged injection wells triggering more earthquakes, study finds

New studies bolster link between quakes and energy production

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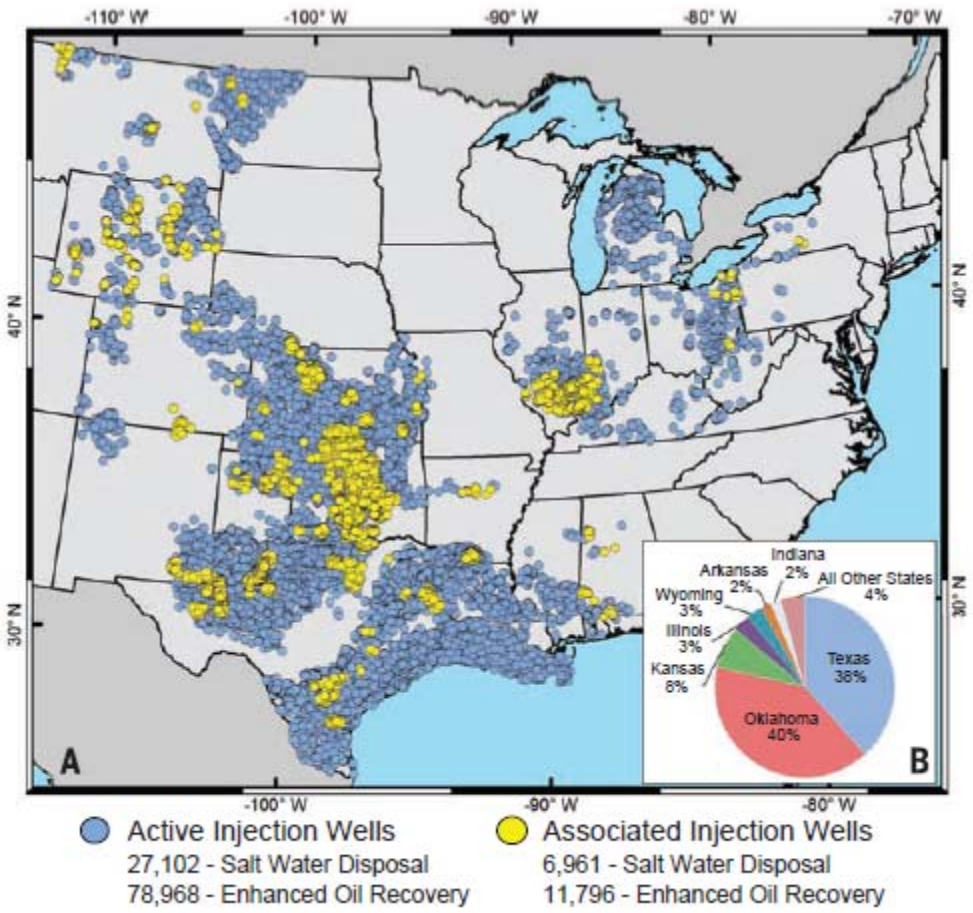
Published: June 18, 2015 1:02 pm

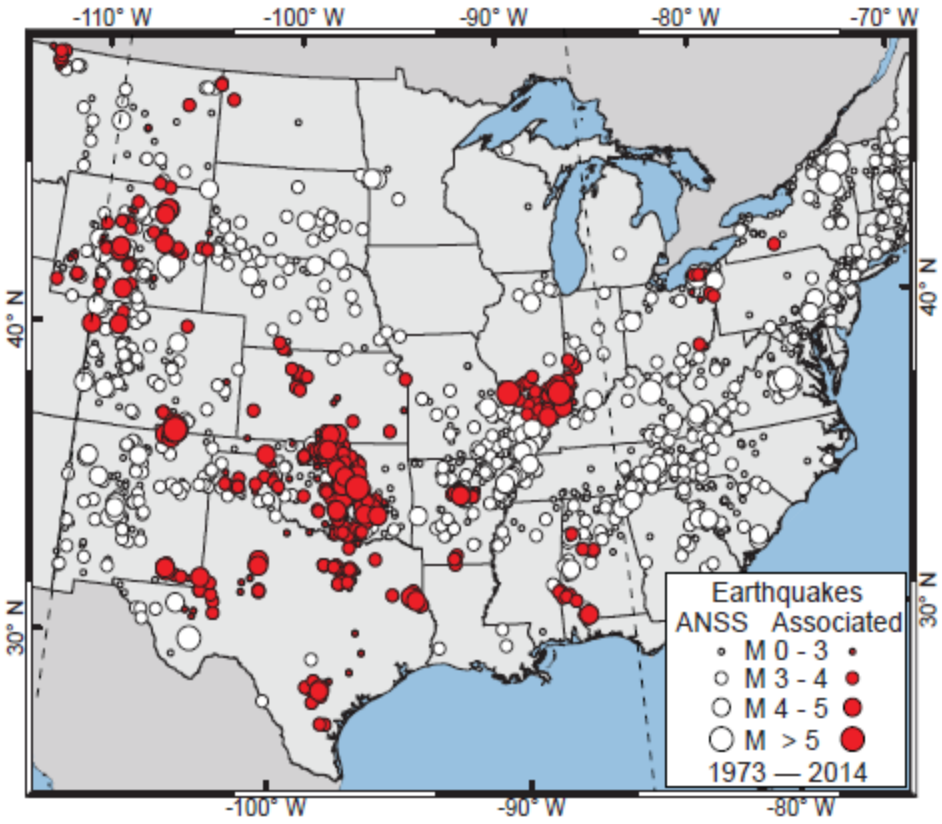


A map showing the location of active injection wells in the Central and Eastern United States. Active injection wells from a database compiled by scientists are shown as blue circles. Active wells associated with earthquakes based on timing and location are shown as yellow circles. The inset pie diagram shows injection wells associated with earthquakes by state. Thirty-eight percent of all quake-associated wells in the database are in Texas; 40 percent are in Oklahoma. CREDIT: Reprinted with permission from Weingarten et al., Science 348:1336 (2015)

Energy company attorneys have called a recent study linking North Texas earthquakes with oil and gas activity "incomplete," "misleading," and "flawed." Texas regulators have also questioned the research, telling *The Dallas Morning News* recently that evidence of human-triggered quakes in Texas is "anecdotal" and not "widely accepted."

But two new scientific papers buttress findings from the earlier study, which was led by researchers at Southern Methodist University and published in April in the journal *Nature Communications*.

A paper out Thursday in the journal *Science* reports an "unprecedented" surge in earthquakes in Texas, Oklahoma and other central U.S. states. It blames the increase on oil and gas operations. "We think the study produces clear evidence that the earthquake rate change is not natural," said Matthew Weingarten, a doctoral candidate in geology at the University of Colorado, Boulder and the study's lead author.



Map showing the locations of earthquakes with magnitudes greater than 0 from January 1,1973 through December 31, 2014. White dots denote earthquakes that are not associated with injection wells. Red dots denote earthquakes that are associated with injection wells. The U.S. mid-continent is defined by the dashed lines inside of the greater Central and Eastern U.S. region. Credit: Reprinted with permission from Weingarten et al., Science 348: 1336 (2015)

Weingarten and his colleagues at the University of Colorado and at the U.S. Geological Survey concluded that the entire increase in earthquake rates in Texas and nearby states was associated with fluid injection wells.

Companies use injection wells to pump wastewater from oil and gas operations into the ground. Some injection wells help stimulate oil and gas production; others, known as saltwater disposal wells, bury leftover fluids from oil and gas extraction. The SMU study concluded that wastewater disposal wells most likely triggered a series of earthquakes west of Fort Worth in 2013 and 2014.

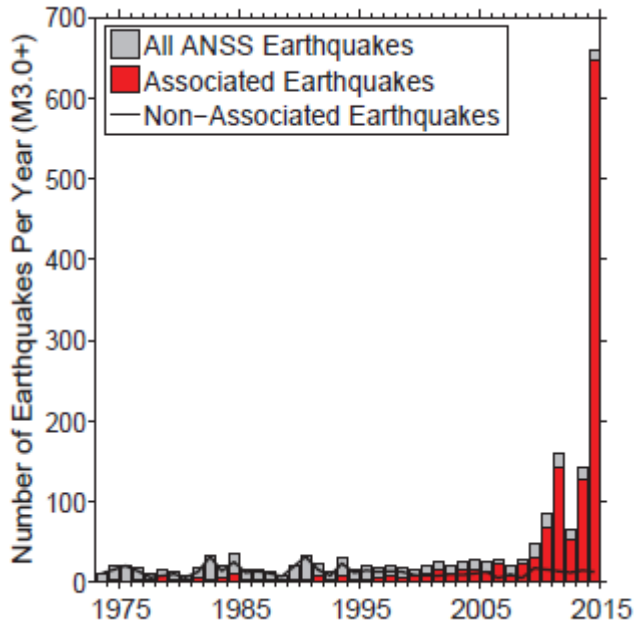
The *Science* paper concluded that wastewater wells are more than 1.5 times as likely as other types of injection wells to be associated with quakes. Wells that inject more than 300,000 barrels of wastewater per month, known as high-rate injection wells, were disproportionately associated with ground shaking.

One of the wells linked with the Fort Worth-area earthquakes averaged approximately 369,000 barrels per month, according to the *Nature Communications* study. The well's permit allows it to inject up to 25,000 barrels per day, or around 750,000 per month. More recently, that well has reduced its injection volume to between 149,000 and 266,000 barrels per month, according to data available through the Web site of the Railroad Commission of Texas, which regulates the oil and gas industry.

The Fort Worth Basin has one of the highest concentrations of active disposal wells in the country, with some areas in the basin containing five wells per two-square-mile area, the study reported.

To reach their conclusions, Weingarten and his colleagues built a database of 180,000 injection wells and compared their locations and the timing of their injections with the location and timing of earthquakes. Quakes that struck within nine miles of an active injection well were considered to be associated with that well. More than 18,000 wells – or about 10 percent — were associated with earthquakes, primarily in Texas and Oklahoma, the researchers reported.

The number of quakes associated with injection wells has soared from a handful per year in the 1970s to more than 650 in 2014, while the rate of earthquakes not near wells has remained the same.



Associated and nonassociated earthquakes per year in the U.S. mid-continent. The gray bars represent the number of 3-magnitude and greater earthquakes per year in the U.S. midcontinent from Jan. 1, 1973 to December 31, 2014. The red bars represent the number of earthquakes that are associated with injection wells. The black line denotes the number of nonassociated earthquakes per year. Over the time period of the catalog, the number of nonassociated earthquakes per year has stayed roughly constant at 10 to 25 per year. Meanwhile, the number of associated earthquakes per year has risen from ~1 to 7 per year in the 1970s to 75 to 190 per year between 2011 and 2013 and >650 earthquakes in 2014. CREDIT: Reprinted with permission from Weingarten et al., Science 348:1336 (2015)

Another study published Thursday in *Science Advances*, a sister publication of *Science*, pinpoints how injection wells can cause the ground to shake.

In recent hearings before the Railroad Commission, operators of two wells that the SMU-led study linked with earthquakes argued that their wells were too far above the earthquake locations – roughly two miles separated the deepest earthquakes from the bottoms of wastewater wells — to have triggered them. But the *Science Advances* paper, by researchers at Stanford University, found that tremors were often located miles away from any wells and separated from peak fluid injections by several months or even years.

Rall Walsh, a Stanford doctoral candidate in geophysics and lead author of the *Science Advances* paper, explained the pressure from fluid injections builds up within the fractures and pores of rock over time. Eventually, that pressure can spread to faraway faults and nudge them apart, causing earthquakes.

That pressure can also propagate down active faults, causing earthquakes that are far deeper than injection wells.

Both studies report that there are many areas in Texas, Oklahoma and throughout the United States where there are high concentrations of wells but no earthquakes. “This highlights the fact that it’s not just well operation that is important in producing an induced quake, it’s really also geologic factors that are important,” said Weingarten.

Those factors include the presence of potentially active faults large enough to create felt earthquakes, as well as fluid pathways from wells to faults through which injection pressure can travel.

Mark Zoback, a Stanford expert on human-triggered earthquakes and senior author of the *Science Advances* paper, is starting a project to map the natural tectonic stresses across Texas in an effort to pinpoint faults that are in danger of slipping.

Last month, SMU received $122,337 from the U.S. Geological Survey to undertake a similar project to map faults in North Texas.