Oklahoma earthquake swarm linked to wastewater injection wells, says study involving CU-Boulder

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Natural Sciences
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Discovery & Innovation

The massive increase in earthquakes in central Oklahoma is likely being caused by the injection of vast amounts of wastewater from oil and gas operations into underground layers of rock, according to a new study led by Cornell University and involving the University of Colorado Boulder.

For the study, appearing today in the journal *Science*, the researchers used hydrogeological models to determine how much pressure the injected wastewater was building up in the pores of the rocks underground. Under high pressure, fluids can seep into existing faults and pry apart the rocks, allowing them to slip past each other more easily and cause earthquakes.

Most previous scientific efforts to link earthquakes and wastewater injection wells have relied largely on the proximity of the earthquakes to the wells and whether the earthquakes increased after the injection started or after injection volumes increased.

Hydrogeological modeling allows scientists to add confidence to the connection between wastewater injection and the earthquakes as well as to determine whether earthquakes farther away from the injection wells might still be linked to the wastewater forced underground.

"Deciding whether an earthquake is induced or natural is a very difficult process scientifically," said Matthew Weingarten, a doctoral student in CU-Boulder's Department of Geological Sciences and a co-author of the paper. "The classic way of determining the likelihood of an induced event is by looking at the seismological data alone. We took the next step in determining causation."

Prior to 2008, Oklahoma averaged about two earthquakes per year with a magnitude of 3.0 or greater, according to the U.S. Geological Survey. This

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year, between Jan. 1 and May 2, there have been 145. Overall, there has been a 40-fold increase in seismic activity in Oklahoma since 2008. The increase in earthquakes in the state coincided with a boom in hydraulic fracturing, which generates a large amount of wastewater.

The research team, led by Cornell's Katie Keranen and including CU-Boulder geological sciences Professor Shemin Ge, analyzed a dense collection of earthquakes that shook central Oklahoma known as the Jones Swarm. This single swarm accounted for a fifth of all seismic activity in the region.

The scientists used data collected from 89 injection wells—including four high-rate wells—and knowledge of the characteristics of the rock layer that the fluid was pumped into to create a map of the pressure in the rocks underground, known as "pore pressure." The model showed that the pore pressure would have been sufficient in the area of the Jones Swarm to cause the earthquakes.

The results are particularly interesting because the Jones Swarm is relatively far, about 15 kilometers, from the four high-rate injection wells that are responsible for the majority of the underground fluid pressure. While a few earthquakes have been recorded in the vicinity of the wells, the scientists believe that the types of faults nearest the wells may require greater pore pressure to cause an earthquake. The faults in the area of the Jones Swarm likely require less pressure to cause an earthquake.

"The faults near the injection wells have too much friction to easily fail," Weingarten said. "But you still have pressure changes far away from those wells and when those pressure changes encounter faults that are closer to failure, you have earthquakes."

The scientists say that hydrogeological modeling will likely be a critical tool in the future for determining whether injection wells and earthquakes are linked when the earthquakes are relatively far from the wells. Hydrogeological models may also be used in the future to set guidelines for how much fluid can be injected safely before the critical pressure is reached that can cause earthquakes in a particular area.

"Induced seismicity is one of the primary challenges we face as shale gas and unconventional hydrocarbon development continues to expand," Ge said. "Adhering to best practices could reduce the risk of inducing seismicity. Some best practices during injection operations include avoiding injecting at high rates, avoiding major faults, and keeping a close eye on how pore pressure changes around injection wells. Before permitting, thorough site-specific hydrogeological studies should be conducted to assess the magnitude and extent of pore pressure changes from the injection."

Other co-authors of the study include Geoff Abers of Cornell and Barbara Bekins of the USGS.

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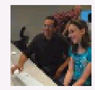
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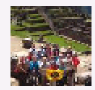
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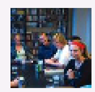
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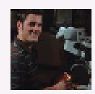
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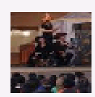
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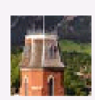
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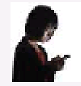

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