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Fracking Wastewater Disposal Linked to Remotely Triggered Quakes

The finding could help scientists identify critically stressed faults.

Water impoundments like this one beside a Colorado oil rig are typical at hydraulic fracturing sites. Underground disposal of the wastewater after fracking may increase seismic risks from remote earthquakes, a new study says.

Photograph by Lynn Johnson, National Geographic

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Fracking for oil and natural gas, and the underground disposal of wastewater that occurs in the process, has been linked to earthquakes in recent years. Now seismologists have

discovered a new twist in that relationship, finding that wastewater injection can also contribute to temblors induced remotely by faraway seismic events.

The finding, detailed in this week's issue of the journal *Science*, is the latest research to show how humans can influence earthquakes. The study found that industrial wastewater disposal made certain areas more prone to seismic activity in the wake of a larger event, linking quakes near wastewater injection sites in the United States to those as far away as Japan and Chile.

"The fluids are driving the faults to their tipping point," lead author Nicholas van der Elst, a seismologist at Columbia University's Lamont-Doherty Earth Observatory, said in a statement.

Scientists have known about "dynamically triggered" temblors for over 20 years, and certain regions were known to be more vulnerable to such earthquakes than others, especially those where underground water superheated by magma can weaken faults and make them more vulnerable to seismic waves generated by a distant quake.

For example, a magnitude 7.9 earthquake in Alaska in 2002 triggered a series of quakes at Yellowstone National Park—nearly 2,000 miles (3,219 kilometers) away—throwing off the schedules of some of its most predictable geysers.

"We had some idea for some time that these fluid-rich systems tend to be sensitive to this kind of triggering," said study coauthor Heather Savage, a geophysicist also at Lamont-Doherty.

Knowing this, van der Elst and his team wondered if areas where humans have artificially created a fluid-rich environment would also be prone to triggered quakes.

Seismic Chain Reactions

To answer this question, the researchers analyzed a catalog of past earthquake recordings in the United States. They focused on earthquakes that occurred shortly after three large quakes: an 8.8-magnitude earthquake in Chile on Feb. 27, 2010, the 9.1-magnitude event off the coast of Japan on March 11, 2011, and an 8.6-magnitude quake in Sumatra, Indonesia on April 12, 2012.

"We saw that three areas in particular have an increase in seismicity in the days following these big events," Savage explained. "These areas were in Texas, Colorado, and Oklahoma."

Most of the triggered quakes occurred in clusters and were too small for humans to notice, but others were more significant. For instance, a 4.1 magnitude triggered quake shook the town of Prague, Oklahoma about 16 hours after the 2010 quake in Chile.

One thing the affected areas in the three states all had in common was that they were located near sites where wastewater injection had been ongoing for decades.

Hydraulic fracturing (or fracking) uses large amounts of water to crack open rocks and help coax oil and gas from underground wells. (See interactive: "Breaking Fuel From the Rock.") After the gas and oil have been extracted, the chemical-laced water is typically pumped back underground. (See related blog post: "Tracing Links Between Fracking and Earthquakes.")

Other research has shown that this practice can induce earthquakes on its own by increasing the pressure on faults and leaving them on the brink of rupturing. For example, a study published earlier in March in the journal *Geology* concluded that a magnitude 5.7 event that struck Prague in 2011—the largest recorded earthquake in the Oklahoma's history—was an induced quake likely triggered by wastewater injection from oil production into wells deep underground. (See related story: "Scientists Say Oil Industry Likely Caused Largest Oklahoma Earthquake.")

A Way to Probe Faults?

It's still unclear why faults that lie near sites with underground water reservoirs are more vulnerable to triggered earthquakes.

"Dynamic triggering itself is actually a very poorly understood phenomenon," said Emily Brodsky, a geophysicist at the University of California, Santa Cruz (UCSC), who was not a coauthor of the current study.

One idea is that the process of wastewater injection leaves local faults "critically loaded" by increasing the fluid pressure exerted on pores in the rock, so that even weak seismic waves from distant earthquakes are enough to disturb them and cause a rupture.

"If you think of a rock like a sponge, you can imagine that fluid resides in the tiny pore spaces between grains," Savage explained in an email. "When fluid pressure is jacked up on faults, like when we pump pressurized fluid underground, it makes faults slip. It's the same concept as an air hockey table: When the air is turned off, it's harder to make the puck slide. When the air is turned on (increase the fluid pressure) the puck (fault) slides more easily."

UCSC's Brodsky called the findings by van der Elst and his colleagues "totally cool" because it means scientists can use dynamically triggered earthquakes to gauge the health of a fault to see if it's close to failure.

To be able to "probe and know what those faults are doing kilometers underground simply by watching how they react to passing seismic waves—that's new," Brodsky said.

Brodsky is the coauthor of a separate study, also appearing in this week's issue of *Science*, that suggests pumping water into and out of an underground reservoir to produce geothermal power can also induce earthquakes.

The findings by van der Elst's team could also help energy companies decide whether pumping wastewater underground is worth the risk of increasing the chances of a triggered quake at a site, Brodsky said.

"That's why it's so important to put numbers to this," Brodsky said, "so that you can really explore the cost-benefit."

This story is part of a special series that explores energy issues. For more, visit The Great Energy Challenge.