Some signs of induced seismicity spotted in Salton Trough's geothermal production fields

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In some parts of Southern California's Brawley Seismic Zone, geothermal energy production may be increasing the background seismicity rate, but changes in earthquake rates elsewhere in the area seem to have natural causes, according to a report published online August 23 in the *Bulletin of the Seismological Society of America*.

Geothermal energy production in the Salton Trough's Brawley Seismic Zone does not have as dramatic of an impact on local seismicity as oil and gas production has had in parts of the central and eastern United States. There, the injection of massive volumes of wastewater from hydrocarbon production has increased the number of earthquakes and aftershocks in states like Oklahoma and Arkansas.

"It's difficult to broadly say that all the earthquakes that occur within a certain space and time at these Salton geothermal fields are going to be induced, because it's much more complicated than that," said U.S. Geological Survey (USGS) seismologist Andrea Llenos. "You have a lot of other natural processes here going on at the same time."

After applying several models to investigate the earthquake behavior from two areas of geothermal production in the Brawley Zone, Llenos and her USGS co-author Andrew Michael concluded that geothermal production is connected to a significant increase in the background seismicity rate in the Salton Sea Geothermal Field (SSGF). The increase in the background rate at the SSGF occurred around 1988, coinciding with a "ramp-up" in geothermal operations in the field that may have led to a net depletion of fluids in the crust there.

But Llenos and Michael found no clear connection between changes in seismicity and geothermal production in the North Brawley Geothermal Field (NBGF). They also found no significant increase in aftershocks in either field that could be connected to production.

The seismologists developed their models using earthquake data collected from within 5 to 10 kilometers of each field, between 1975 and 2012 for the SSGF and 1980 and 2012 for the NBGF.

Unlike the seismically quiet central U.S., the Salton Trough has long been the scene of significant seismic activity. The trough marks a transition between extensional rifting—where the crust is stretching and thinning beneath the Gulf of California to the south—to strike-slip motion along the San Andreas Fault system to the north. The area is prone to earthquake swarms, including an August 2012 swarm of more than 600 small earthquakes that occurred over two days near the town of Brawley.

High heat flow through the crust in the Salton Trough makes it an attractive area for geothermal energy production, with four active geothermal fields that together generate more than 650 megawatts of power. Geothermal energy is produced when hot water is extracted from the ground as steam that powers generators. The water from the condensed steam is then injected back into the ground.

At the time of the 2012 Brawley swarm, Llenos and Michael were finishing up a study of earthquake rate changes in Oklahoma and Arkansas, published in 2013, to evaluate whether those changes were induced by wastewater injection. "We wanted to see then if the tools we were using in the eastern and central U.S., which were working pretty well to distinguish natural and induced seismicity, would work as well or at all in the Salton Trough," Llenos explained.

The energy production techniques differ considerably in the two regions. In the oilfields of Oklahoma, for example, the wastewater produced during oil recovery and injected back into the ground "increases the volume of fluids significantly at depth" Llenos said. "But for geothermal energy production, the field operators try to maintain a net fluid balance." In some fields, almost 90 percent of the fluids used in geothermal production get injected back into the ground shortly after they are extracted, Llenos noted.

This difference may in part affect the production of aftershocks in each region, Llenos suggested. "In places like Oklahoma, the sudden changes in pressure at depth might bring many faults closer to their failure threshold," she said. "So if all these faults around an earthquake are closer to failure, we found that many more aftershocks are triggered as a result. We don't see that kind of drastic change in the Brawley Seismic Zone."

Because the scientists had access to a much richer set of earthquake data in California than was available for the central U.S., "we were able to use more sophisticated models and tests here," Llenos said. "For example, we could analyze how aftershock triggering varies with distance between earthquakes much better here than we were able to in the central and eastern U.S."

Since their 2013 study, however, more instruments have been placed and more seismicity data have been collected in the central U.S. "Now that there's more seismic network coverage in places like Oklahoma, we may someday be able to take the kinds of models we used here and reapply them in the central states," said Llenos.

More information: "Characterizing Potentially Induced Earthquake

Rate Changes in the Brawley Seismic Zone, Southern California," DOI: 10.1785/0120150053

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