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Geoscientist hopes to make induced earthquakes predictable

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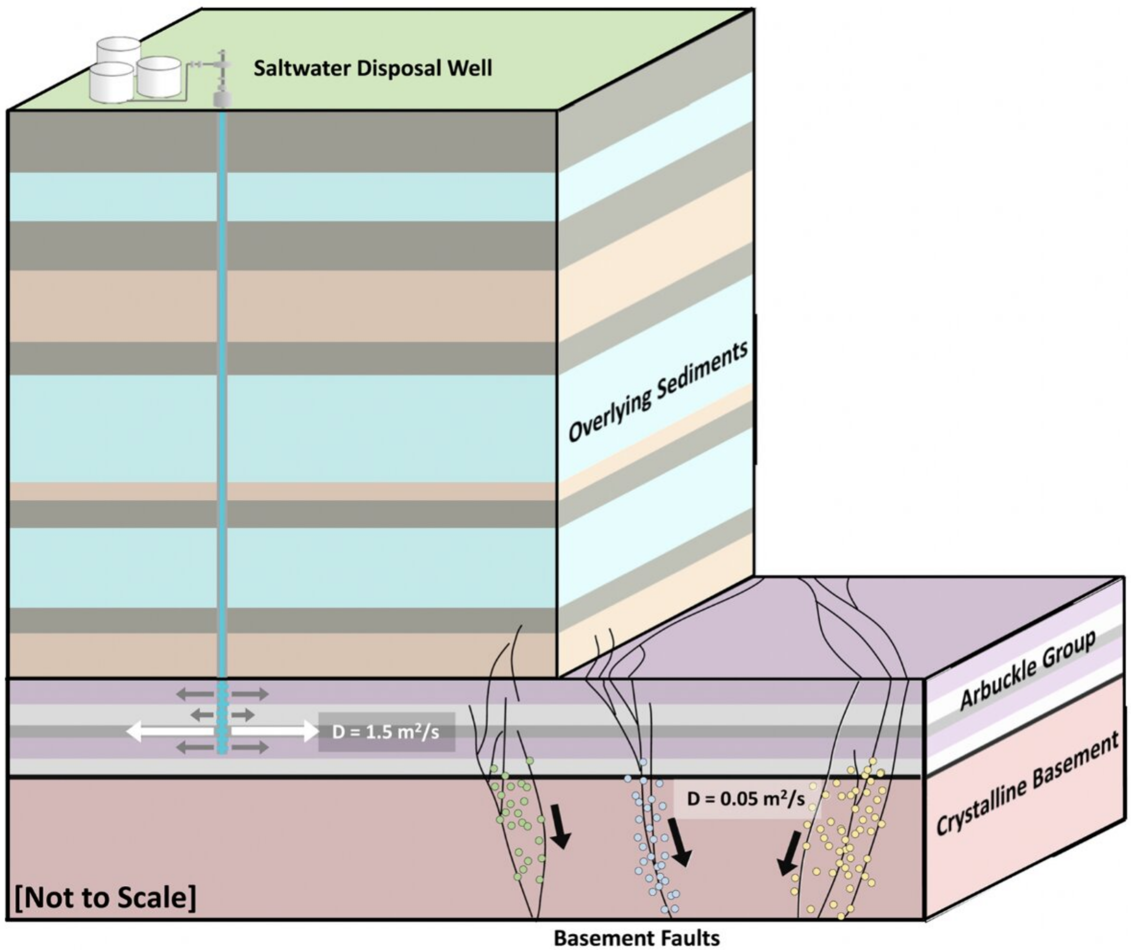

This simplified hydrology model shows the subsurface of Oklahoma. The Arbuckle Group is the area where most wastewater is injected. This layer allows fluid to move easily to distant areas. The added water causes stress as it travels and can cause earthquakes when it encounters pre-existing faults. Credit:

University of Oklahoma

University of Oklahoma Mewbourne College of Earth and Energy assistant professor Xiaowei Chen and a group of geoscientists from Arizona State University and the University of California, Berkeley, have created a model to forecast induced earthquake activity from the disposal of wastewater after oil and gas production.

"In this region of the country, for every barrel of oil produced from the ground, usually between eight and nine barrels of water are also extracted from many wells," said Chen.

The large amount of water leads to a problem for oil producers—what to do with it?

Also called brine, this wastewater contains salt, minerals and trace amounts of oil, making it unusable for consumption or agricultural purposes and cost-prohibitive to treat. It is disposed of by injecting it back into the earth, deep into porous rock formations.

Wastewater injection can cause earthquakes, explained Chen, and while most of the recent earthquakes in Oklahoma have been small, several have been in excess of 3.0 on the Richter scale.

Chen and a team of researchers, led by Guang Zhai and Manoochehr Shirzaei from ASU, and Michael Manga from UC Berkeley, set out to find a way to make induced earthquakes in Oklahoma predictable and small.

Their method, explained Chen, was to "create a model that correlates injected wastewater volume with stress changes on nearby faults and the number of earthquakes in that area."

Finding the Formula

Forecasting the amount of seismic activity from wastewater injection is difficult because it involves accounting for numerous variables:

- How easily brine can move through the rock in a given region
- Where and how much brine is injected
- The regional stress on those faults
- The presence of existing geological faults

The team tackled each issue.

Chen and her fellow researchers studied subsurface hydrology parameters—how fast fluid moves within porous rocks and how quickly introduced fluid changes the stress in the subsurface basement. This is important because the subsurface basement is the location of Oklahoma's induced earthquakes.

While the ASU team used satellite data to determine subsurface hydrology parameters, Chen focused on space and time distributions of earthquakes, and determined hydrology parameters by looking at how fast earthquakes move away from injection zones. By comparing both sets of data, researchers further increased the accuracy of their model.

As it turns out, the Arbuckle Group, a sedimentary layer that sits on top of the subsurface basement deep within the earth, is especially permeable, allowing brine, and therefor earthquakes, to easily spread.

"When we inject brine into the Arbuckle Group at a depth of 1-3 kilometers, it can transport through the porous rocks, modifying stresses and causing earthquakes on basement faults," said Chen.

Next, researchers can plug in the amount of fluid into the model. By adding the volume of fluid injected in a particular area into their model, they can determine the stress it will place on that region as it spreads.

With the brine variables accounted for, researchers then added information about pre-existing faults into regional calculations. The more researchers know about a particular area, the more accurate the data will be.

"If we are going to operate in an area where we don't have any prior seismicity, it will be a little challenging to forecast accurately," said Chen. "But by operating in a new area and taking real-time parameters, operators and researchers should be able to forecast future behavior."

Results

Chen hopes that by following the results of the models she helped create, oil operators in the state can create new protocols for how much wastewater to inject and where.

This could help prevent large induced earthquakes in Oklahoma. Chen does not believe forthcoming protocols will end induced seismicity altogether, but rather will help cap earthquake size and rate with restricted injection control. This method can forecast future induced seismicity.

Chen foresees a protocol similar to tornado watches—a window of time where Oklahomans are warned they may feel minor tremors in a region of the state.

According to Chen, this is an area where the close working ties between geoscientists and petroleum engineers will need to be even stronger. So far, her research has garnered interest from both geoscientists and petroleum engineers in industry and academia.

More information: Guang Zhai et al, Pore-pressure diffusion, enhanced by poroelastic stresses, controls induced seismicity in Oklahoma, *Proceedings of the National Academy of Sciences* (2019). DOI: 10.1073/pnas.1819225116

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