Pore pressure diffusion led to microseismicity at Illinois basin carbon sequestration site, modeling study finds

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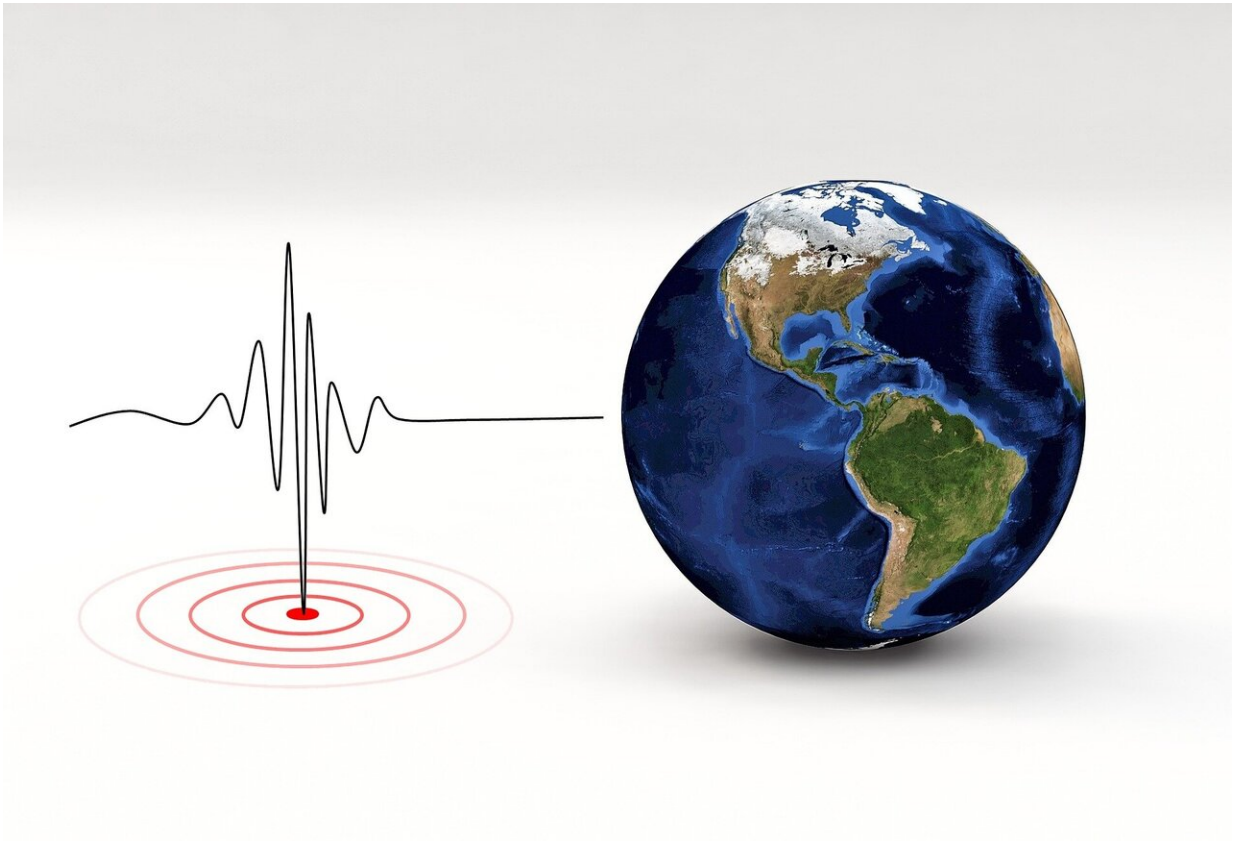

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Pore pressure diffusion generated by carbon dioxide injected

underground at a carbon storage site in the Illinois Basin is the likely cause of hundreds of microearthquakes that took place at the site between 2011 and 2012, according to a new analysis.

The modeling study published in the *Bulletin of the Seismological Society of America* indicates that pressure diffusion along existing faults into the basement rock could have destabilized the faults where the microseismicity—ranging from Mw -2 to 1—occurred, said Ruben Juanes of MIT and colleagues.

There are some similarities between CO_2 injection and wastewater injection from oil and gas operations, although globally the volumes of injected wastewater so far exceed that of injected CO_2. Wastewater injection has induced small to moderate-sized earthquakes around the world, however, making it important to study how CO_2 injection produces seismicity and whether it might also induce larger earthquakes.

The new findings confirm the importance of characterizing subsurface faults in places selected for CO_2 sequestration, the researchers note.

The first injection period at the Illinois Basin-Decatur Project (IBDP) ran from November 2011 to November 2014, during which time one million tons of CO_2 were injected to a depth of 2 kilometers underground. The researchers focused on the first year of CO_2 injection at the project.

The IBDP injection layer is separated from the basement rock by a sandstone layer that is not very porous or permeable, leading researchers to wonder how CO_2 injection could have reached the basement to trigger seismicity.

The model created by Juanes and colleagues shows that changes in rock pore pressure from the injection traveled along faults that connected the

injection layer and the basement.

"During fluid injection, the pore pressure increases at the injection well and diffuses away from the well because of fluid migration. This is analogous to how temperature 'diffuses away' from hot areas to cold areas," Juanes explained.

"As a result of this pressure increase, the effective stress on a fault will decrease, resulting in the destabilization of the fault."

Fluid injection can also expand rock, in a mechanism called poroelastic stress. The deforming rock can lead to stress changes that either destabilize or stabilize faults. In the IBDP case, the poroelastic effect stabilized the faults, Juanes and colleagues found.

Their analysis also suggests that the faults hosting the microearthquakes were very close to failing prior to CO_2 injection. Characterizing these small faults—where they are and how close they are to failure—poses a significant challenge to carbon sequestration projects, Juanes noted.

"The main challenge is that remote sensing methods rely mostly on propagation of seismic waves through the surface," said Josimar Silva, first author of the study and a postdoc at MIT during the project. "Seismic waves attenuate rapidly for distances away from the source, and therefore have limited resolution when they reach the depths of interest."

One way to illuminate smaller faults at a carbon storage site might be to start with small-scale injection, he added.

"CO_2 injection at Decatur is a good example. The first period of injection, the one we analyzed in the paper, led to hundreds of microearthquakes. The second period of injection, which took place at a

shallower depth and not as close to the faulted basement, resulted in virtually no seismicity," Juanes said.

Injection rates in CO_2 projects have been "much, much lower" than wastewater injection rates in the 2000s and 2010s, said Juanes, which might explain why moderate-sized induced seismicity hasn't been seen at carbon sequestration projects.

"But another explanation is that generally, better subsurface characterization has been done for CO_2 sequestration prior to injection than in the early days of geologic wastewater disposal, where it was common to inject into, or very close to, the faulted basement rock," he added.

More information: Josimar A. Silva et al, Mechanisms for Microseismicity Occurrence Due to CO2 Injection at Decatur, Illinois: A Coupled Multiphase Flow and Geomechanics Perspective, *Bulletin of the Seismological Society of America* (2024). DOI: 10.1785/0120230160

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