Rock permeability, microquakes link may be a boon for geothermal energy

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Using machine learning, researchers found a link between seismic activity and geothermal energy extraction efficiency, which could provide a potential boost for this renewable energy source. Credit: Pixabay

Using machine learning, researchers at Penn State have tied low-magnitude microearthquakes to the permeability of subsurface rocks beneath the Earth, a discovery that could have implications for improving geothermal energy transfer.

Generating geothermal energy requires a permeable subsurface to efficiently release heat when cold fluids are forced into the rock. This research reveals the optimum times for efficient energy transfer by exposing the link to microearthquakes, which are monitored on the surface through seismometers. The team published their findings in *Nature Communications*.

Using two datasets from the EGS Collab and Utah FORGE demonstration projects, researchers used machine learning to extract the "noise" found in the data that obscured the link. Researchers then used machine learning to create a model from one site and successfully applied it to the other—a process called transfer learning—suggesting that the link was formed based on general physics of subsurface rocks. That means it's likely to be universally true for all geothermal energy sites, the researchers said.

"Success of transfer learning confirms the generalizability of the models," said Pengliang Yu, postdoctoral scholar at Penn State and lead author of the study. "This suggests seismic monitoring could broadly be used to improve geothermal energy transfer efficiencies across a wide range of sites."

Increasing rock permeability is critical to a range of energy extraction methods, Yu said. Rock permeability impacts traditional fossil fuel recovery as well as renewable energies including hydrogen production. Hydrofracturing methods introduce cold fluids into the subsurface through porous rock, which creates high pressures that break the rock in tension or shear.

This process creates microearthquakes similar to naturally occurring earthquakes, but at a much smaller scale. By increasing the permeability of the rock, energies such as heat and hydrocarbons are able to more easily reach the surface.

Yu said their algorithm showed a direct link, meaning the rock became the most permeable when the seismic activity was strongest.

Identifying the link between seismic activity and rock permeability improves the ability to extract energy while ensuring microquakes stay below the threshold that could cause damage or be observed by the public.

"Machine learning played a key role in uncovering the relationship between seismic activity and rock permeability," said co-author Parisa Shokouhi, professor of engineering science and mechanics in the College of Engineering. "It helped identify the important attributes of the seismic data for predicting rock permeability evolution. We constrained the machine learning algorithm to ensure a physically meaningful model. In return, the model prediction revealed a previously unknown physical link between seismic data and rock permeability."

Increasing the availability of geothermal energy would lessen dependence on fossil fuels, the researchers said. Additionally, they noted that linking rock permeability to microquakes can be useful in monitoring gas movement for carbon sequestration and the production and storage of subsurface hydrogen.

The research is part of a larger project to decrease the cost and increase production of geothermal energy and use machine learning to better understand and predict earthquakes, including microquakes.

"Yu's work is part of our effort to advance geothermal exploration and geothermal energy production using machine learning methods," said co-author Chris Marone, professor of geosciences at Penn State. "Our lab studies show clear connections between the evolution of elastic properties prior to lab earthquakes, and we are excited to see that similar relationships are observed in nature."

More information: Pengliang Yu et al, Crustal permeability generated through microearthquakes is constrained by seismic moment, *Nature Communications* (2024). DOI: 10.1038/s41467-024-46238-3

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