Study yields a new scale of earthquake understanding

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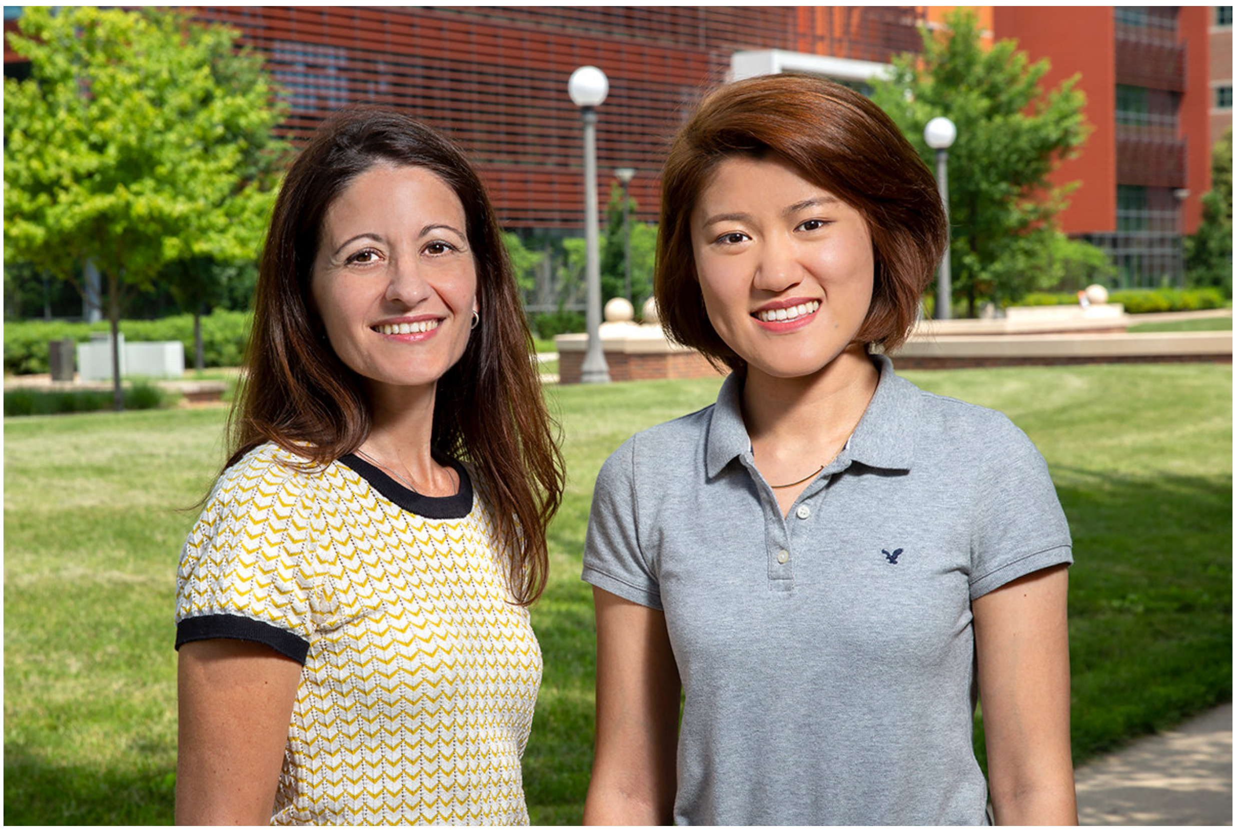

Civil and environmental engineering professor Rosa Espinosa-Marzal, left, and graduate student Yijue Diao used nanoscale techniques to study earthquake dynamics and found that, under the right conditions, some rocks dissolve and may cause faults to slip. Credit: Joyce Seay-Knoblauch

Nanoscale knowledge of the relationships between water, friction and mineral chemistry could lead to a better understanding of earthquake dynamics, researchers said in a new study. Engineers at the University of Illinois at Urbana-Champaign used microscopic friction measurements to confirm that, under the right conditions, some rocks can dissolve and may cause faults to slip.

The study, published in the journal *Nature Communications*, closely examines how water and calcite—a mineral that is very common in the Earth's crust—interact at various pressures and groundwater compositions to influence frictional forces along faults.

"Water is everywhere in these systems," said Rosa Espinosa-Marzal, a civil and environmental engineering professor and co-author of the study. "There is water on the surface of minerals and in the pore spaces between mineral grains in rocks. This is especially true with calcite-containing rocks because of water's affinity to the mineral."

According to the researchers, other studies have correlated the presence of water with fault movement and earthquakes, but the exact mechanism remained elusive. This observation is particularly prevalent in areas where fracking operations are taking place—a process that involves a lot of water.

The study focuses on calcite-rich rocks in the presence of brine—naturally occurring salty groundwater—along fault surfaces. The rock surfaces that slide past each other along faults are not smooth. The researchers zoomed in on the naturally occurring tiny imperfections or unevenness on rocks' surfaces, called asperities, at which friction and wear originate when the two surfaces slide past each other.

"The chemical and physical properties of faulted rocks and mechanical conditions in these systems are variable and complex, making it difficult to take every detail into account when trying to answer these types of questions," Espinosa-Marzal said. "So, to help understand water's role in fault dynamics, we looked at a scaled-down, simplified model by examining single asperities on individual calcite crystals."

For the experiments, the team submerged calcite crystals in brine solutions at various concentrations and subjected them to different pressures to simulate a natural fault setting. Once the crystals were in equilibrium with the solution, they used an atomic force microscope to drag a tiny arm with a silicon tip—to simulate the asperity—across the crystal to measure changes in friction.

In most of the experiments, the researchers first found what they expected: As the pressure applied on the crystals increased, it became more difficult to drag the tip across the crystal's surface. However, when they increased pressure to a certain point and the tip was moved slowly enough, the tip began to slide more easily across the crystal.

"This tells us that something has happened to this tiny asperity under higher pressures that caused a decrease in friction," said graduate student and co-author Yijue Diao. "The atomic force microscope also allows us to image the crystal surface, and we can see that the groove increased in size, confirming that calcite had dissolved under pressure. The dissolved mineral and water acted as a good lubricant, thereby causing the observed weakening of the single-asperity contact."

"This shows that studies such as these warrant serious consideration in future work," Espinosa-Marzal said. The researchers acknowledge that there are still many questions to address related to this research. However, their work demonstrates that certain brine-calcite interactions, under applied stress, induce dissolution and decrease the frictional strength at the single-asperity scale.

"Our research also suggests that it might be possible to mitigate earthquake risk by purposely changing brine compositions in areas that contain calcite-rich rocks. This consideration could be beneficial in areas where fracking is taking place, but this concept requires much more careful investigation," Espinosa-Marzal said.

"As a young scientist who works at the nanoscale, I never thought that earthquake dynamics would be the type of thing I would be researching," Diao said. "However, we have learned so much about things at the macroscale that nanoscale studies like ours can reveal new critical insights into many large-scale natural phenomena."

More information: Yijue Diao et al, The role of water in fault lubrication, *Nature Communications* (2018). DOI: 10.1038/s41467-018-04782-9

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